GENERAL SCIENCE INSTRUCTION IN THE GRADES

PART I.
A QUANTITATIVE ANALYSIS OF GENERAL SCIENCE TEXTS

PART II.
THE REACTION OF CHILDREN OF THE LAST THREE GRAMMAR GRADES TO SCIENCE

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PART I.

CHAPTER I.

THE PRESENT STATUS OF GENERAL SCIENCE.

THE presentation of General Science may be defined as a method of teaching the laws of Nature and their applications in the inventions of man without considering the boundaries of those groups into which scientific knowledge is usually divided: astronomy, botany, chemistry, physics, physiography, . . . zoölogy. The method is not new, for books treating of natural phenomena in this general manner were published fifty years and more ago as readers for the schools, and at any given date in the last half century one or more such texts have been on the market. In many, if not most, of them the biological phases of science as embodied in Nature Study have predominated.

The present tide of interest in the content and method of General Science dates from about 1912, when the publication of texts in rapid sequence was begun. The United States Commissioner of Education's Report for 1890-1910, published in 1910, had just announced the startling fact that the sciences were rapidly waning in popularity in high schools, as evidenced by the decreasing per cent of enrollment. The school journals had published several articles condemning "university domination" of high-school science, the criticism being largely directed at the types of entrance examinations, and other requirements of college-entrance boards, which seemed to demand that the content and method of high-school science be essentially that of a diluted college course, with emphasis on laws and theories rather than applications and everyday illustrations.

If causes are to be judged by results, the psychological moment had arrived for radically altering the methods of teaching science to pupils in early adolescence, for from 1911 to the present date (January 1, 1920) twenty-two texts have been published, also many laboratory manuals, either independent or accompanying texts; a quarterly journal devoted exclusively to General Science has entered its third volume; departments of General Science have been opened in several educational journals; committees under the auspices of the National Educational Association, the Association of Science and Mathematics Teachers, etc., have had official status and published reports, and the in-

clusion of General Science in the eighth and ninth grades has spread rapidly throughout the nation.

Of course the new subject has met with strong opposition, and each of its claims has been countered by closely related criticisms.[1] It is unfortunate that but few of the arguments for or against General Science have been based on any accurate examination of texts or manuals.

The writer, in 1917,[2] examined the ten textbooks then on the market page by page, and made a critical analysis of the purpose, subject-matter, and method of treatment found therein. In the spring of 1919 the list was again brought up to date, and eighteen texts which had been advertised or reviewed in school journals were examined, and an analysis of these texts, greatly amplified and considering many phases not included in the first analysis, comprises the first portion of this study.

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[1] "A Bibliography of General Science," W. L. Eikenberry, General Science Quarterly, Vol. II., No. 3, p. 406.

[2] "A Quantitative Analysis of General Science," H. A. Webb, School of Science and Mathematics, Vol. XVII., No. 6, pp. 534-545; June, 1917.

CHAPTER II.

METHOD OF THE ANALYSIS.

THE eighteen texts contain a total of 6,638 pages of instruction, all tables of contents, introductions, prefaces, general review questions, appendices, and indices excluded. These pages were carefully examined one by one, and an entry made on a card for every half page, labeling each card with the title of the topic, the name of the book, and page number of the topic, to permit future identification. The cards were then arranged under headings of the generally recognized branches of scientific knowledge, then rearranged under the important topics in each of these special sciences. This distribution, and a number of subsequent ones by texts, by size of topics, etc., form the minute data from which the tables of this study are obtained.

The topic. The employment of a certain degree of personal judgment was inevitable in these arrangements. It was first necessary to decide upon a title for the subject-matter discussed in a given half page. For example, if the instrument by which the weight of air may be measured was described and illustrated, the word "barometer" was written as the title, especially if the paragraph or page heading gave the hint.

The science. It was necessary to judge whether the topic was properly included in any of the several principal divisions of science, and, if so, which one. While the barometer is discussed in several sciences, notably chemistry, physics, meteorology, yet its principle is a law of physics fundamental to all the phenomena of the mechanics of fluids. Chemistry and meteorology deal with the applications and interpretations of air pressure after it has been measured, rather than with the workings of the barometer. Texts in physics treat the topic more fully than do texts in the other sciences. The assignment of the topic "barometer" to the science of physics seems just and reasonable from these considerations.

In like manner each topic was assigned to some science, or to a purely miscellaneous group, the best possible individual judgment being brought to bear on each decision. The writer has had teaching experience in each and every subject of the high-school science curriculum, and founds these judgments upon the knowledge thus acquired.

The unit group. Closely related topics were grouped to

reduce the number of units to be handled. The content of General Science could be far more easily, and almost as accurately, judged from an examination of these groups than from the display of the great mass of minute data. The topic "barometer" thus becomes linked with other topics of air pressure and measurement as considered in physics, under a more general heading, and forms a medium-sized unit of subject-matter neither as small as a paragraph nor as large as a chapter.

CHAPTER III.

THE SUBJECT-MATTER OF GENERAL SCIENCE.

It was found that the space devoted to instruction in the eighteen texts examined comprised topics which might be considered as belonging to eight large science groups, which ranked in importance as to space as follows:

	Pages		*Pages*
Physics	2,212.5	Physiography	1,264.5
Biology	908.0	Physiology	885.5
Chemistry	632.0	Household Art	343.5
Astronomy	271.5	Miscellaneous	120.5

Table I. shows the unit groups of these sciences ranked in the order, first, of the number of texts which include topics of the group; second, the number of pages devoted to the group in these texts. The column headed "Test Topics" will be referred to in the latter portion of this study. If ten texts be considered as a clear majority of the eighteen, it is seen that there is considerable agreement as to the most suitable subject-matter in the principal sciences, the number of unit groups, and the number of pages devoted to topics found in ten or more texts having the following percentage for each science:

Science	*Pages* %	*Unit Groups* %	Science	*Pages* %	*Unit Groups* %
Physiography	80.5	47.8	Physics	80.3	54.4
Physiology	72.6	33.3	Astronomy	70.2	40.0
Chemistry	64.5	34.2	Biology (Botany)	63.1	43.5
Household Art	56.6	15.4	Zoölogy	0.	0.
			Miscellaneous	0.	0.

In every science, except zoölogy, over half of the pages of instruction are devoted to the discussion of topics which are also found in a majority of the other texts. A general conclusion may certainly be drawn from this condition—that General Science is by no means a mass of unrelated subject-matter, and that there is a recognition of the acceptability of a large mass of the subject-matter of the so-called "special sciences" by the authors of these texts.

TABLE I.

THE TOPICS OF GENERAL SCIENCE.

In PHYSICS.

Topic	Number of Books	Number of Pages	Test Topics
1. Transfer of Heat. (Radiation, Conduction, Convection, and Applications)	18	252.5	1
2. Thermometers	18	84.5	1
3. Air Pressure and Measurement. Barometers	17	154.	1
4. Energy, Types of. Momentum, Inertia, etc.	15	82.	1
5. Three Molecular States of Matter	15	64.	1
6. Quantity of Heat. Specific Heat	15	54.	1
7. Levers	14	55.	1
8. Magnets, Permanent	13	66.5	1
9. Specific Gravity, Buoyancy, etc.	13	43.5	1
10. Pumps, and Their Uses	13	43.	1
11. Reflection of Light. Mirrors	13	39.	1
12. The Inclined Plane	13	37.	1
13. Mass, or Weight of Matter. Gravity	13	32.5	1
14. The Spectrum. Rainbows, etc.	13	28.5	1
15. Electromagnets, and Applications	12	56.5	1
16. Boiling and Freezing Points	12	56.5	1
17. Ice Making, Principle of	12	54.5	1
18. Refraction of Light. Lenses, etc.	12	45.	1
19. Electrical Cells	12	34.	1
20. Dynamos and Motors	11	48.	1
21. The Steam Engine	11	39.	1
22. Expansion from Heat	11	38.	1
23. Nature of Light	11	38.	1
24. Artificial Lighting, Principles of	10	71.	1
25. Sound	10	58.	1
26. Water and Wind Power	10	50.	--
27. Electric Heating and Lighting	10	38.5	--
28. Liquid Pressure, Laws of. Hydraulics	10	38.5	--
29. Evaporation. Vapor Pressure	10	29.	--
30. Solutions. Physical Properties of Water	10	24.5	--
31. Pulleys	10	22.	--
32. Static Electricity	9	29.5	--
33. Friction Producing Heat	9	18.5	--
34. Distillation	9	14.5	--
35. Electroplating	9	13.5	--
36. Siphons	9	8.5	--
37. Weights and Measures	8	53.	--
38. Cohesion and Adhesion. Capillarity	8	21.5	--
39. Gasoline Engine	8	21.	--
40. Heat, Theoretical Nature of	8	17.5	--
41. Machines, and Their Applications	7	65.	--
42. Resolution of Forces. Kites, Airplanes, etc.	7	42.	--
43. Diffusion of Gases. Kinetic Molecular Hypothesis	7	11.5	--
44. Insolation. Absorption of Heat by Air	6	13.5	--
45. Units of Electrical Measure	5	11.	--
46. Color, Theory of	5	11.	--
47. Storage Batteries	4	7.	--
48. Explosions. Energy of Expanding Gases	4	5.5	--
49. Electrical Appliances, Fuses, Switches, etc.	3	21.	--
50. Electrical Transformers	3	7.	--
51. The Pendulum	2	9.	--
52. Bridges, Construction of	1	8.5	--
53. Physical Laws, General Definition	1	1.5	--
54. Angular Measurement	1	1.5	--
55. Hardness of Substances, Scale of	1	1.	--
56. Absorption of Gases	1	.5	--
Total pages of topics in Physics		2,212.5	

In PHYSIOGRAPHY.

	Topic	*Number of Books*	*Number of Pages*	*Test Topics*
1.	Humidity. Precipitation of All Kinds	17	181.5	3
2.	Winds and Storms, Causes of	17	178.	3
3.	Soil Formation. Weathering. Types	16	145.5	3
4.	Weather Forecasts, and Weather Maps	16	93.	2
5.	Ground Water, Caves, Springs, etc.	14	65.5	2
6.	Erosion, Deposition, Rivers, Lakes	13	127.5	2
7.	Irrigation, Drainage	13	40.5	2
8.	Coal, Occurrence, and Formation	13	26.	2
9.	Climate, Conditions and Causes	11	62.	2
10.	Rocks, Igneous and Sedimentary	10	80.5	2
11.	Thunder Storms. Lightning	10	18.	1
12.	Tillage of the Soil, Effects of	6	25.5	--
13.	Oil Wells, Petroleum, Natural Gas, etc.	6	23.5	--
14.	Glaciers, Icebergs	5	37.	--
15.	Volcanoes, Earthquakes	4	31.	--
16.	Mountains, How Formed	4	29.5	--
17.	Land Forms, Coast Lines, Bays, etc.	3	55.	--
18.	The Ocean. Currents, etc.	3	20.	--
19.	The Earth's Crust	3	8.	--
20.	Topographical Maps, Rules for Making	2	12.5	--
21.	Mines, Their Construction. Mining	2	3.	--
22.	The Aurora Borealis	2	1.5	--
	Total pages of topics in Physiography		1,264.5	

In BIOLOGY.

BOTANY

	Topic	*Number of Books*	*Number of Pages*	*Test Topics*
1.	Photosynthesis	16	68.	2
2.	Yeasts and Molds	16	60.5	2
3.	Flowers, Structure and Function	15	46.5	2
4.	Roots, Structure and Function. Osmosis	14	46.5	2
5.	Eugenic Bacteria. Fixation of Nitrogen	14	31.	2
6.	Seeds, Dispersal, Germination	13	39.5	2
7.	Stems, Trees as Types	12	69.5	2
8.	Bacteria, Structure of (not hygiene)	10	33.5	2
9.	Leaves, Structure of	10	27.	2
10.	Transpiration	10	24.	2
11.	Cells. Protoplasm	8	23.5	--
12.	Fertilizers, and Plant Foods	7	32.	--
13.	Plant Life, Miscellaneous Types	7	16.5	--
14.	Distribution and Variety of Plants	6	38.5	--
15.	Artificial Plant Propagation. Budding, Grafting, etc.	6	22.	--
16.	Higher Fungi, Toadstools, etc.	6	14.	--
17.	Heredity. Natural and Artificial Selection	5	49.5	--
18.	Algæ	5	17.	--
19.	Gardening, and Cultivation of Plants	4	29.	--
20.	Ferns and Mosses	4	6.	--
21.	Plant Diseases	3	11.5	--
22.	Sap of Plants. Juices, etc.	2	2.	--
	ZOÖLOGY			
23.	Insects	9	34.5	2
24.	Types of Animals. Vertebrates, Invertebrates	6	34.	1
25.	Amphibians. Life History of Frog	6	12.5	1
26.	Amœba	6	12.	1
27.	Animal Distribution Over the Earth	5	28.5	--
28.	Birds	5	16.	--
29.	Fish	4	7.5	--
30.	Reproduction in Animals	4	6.5	--
31.	Worms	4	5.	--
32.	Mammals	4	4.5	--
33.	Animals Useful and Harmful to Man	3	12.5	--
34.	Reptiles	3	2.	--
35.	Animal Parasites and Pests	2	13.	--
36.	Low Forms of Animal Life. Hydra, Coral	2	4.5	--
37.	Crawfish	2	4.	--
38.	Mollusks	2	3.	--
39.	Instinct	2	1.	--
	Total pages of topics in Biology		908.0	

In PHYSIOLOGY—HYGIENE.

Topic	Number of Books	Number of Pages	Test Topics
1. Bacteria, and Contagious Diseases	15	206.	4
2. Pure Water Supply, How Obtained	15	98.	3
3. Insect Carriers of Disease	13	54.5	3
4. Respiration	13	50.5	3
5. Digestion	12	79.5	3
6. The Eye	12	60.	3
7. Narcotics and Stimulants	12	52.	3
8. The Circulation	10	42.	3
9. Sewage Disposal	7	35.5	--
10. The Nervous System	7	32.5	--
11. The Ear	7	13.	--
12. First Aid	6	34.5	--
13. The Skeleton. Bones	6	21.5	--
14. Excretion	5	23.5	--
15. Muscles	5	13.5	--
16. Pure Air. Harmfulness of Dust	5	12.	--
17. Sanitary Plumbing	4	17.5	--
18. Hygiene, Miscellaneous Discussion of	3	26.5	--
19. Animal Parasites, Tapeworm, Hookworm	3	2.5	--
20. The Special Senses, Miscellaneous	2	3.5	--
21. Touch	2	2.	--
22. Taste	2	1.5	--
23. Smell	2	1.	--
24. Ductless Glands	1	2.5	--
Total pages of topics in Physiology—Hygiene		885.5	

In CHEMISTRY.

Topic	Number of Books	Number of Pages	Test Topics
1. Combustion	18	75.5	2
2. Composition of the Atmosphere	16	38.	2
3. Oxygen, Occurrence, Preparation, etc.	14	37.	2
4. Carbon Dioxide, Preparation, etc.	14	28.	2
5. Composition of Water. Electrolysis	13	20.	2
6. Elements, Mixtures, and Compounds	12	33.5	2
7. Hydrogen, Preparation and Properties	12	23.5	2
8. Hardness of Water	12	14.5	2
9. Physical and Chemical Changes	11	31.	2
10. Nitrogen, Preparation and Properties	11	12.5	1
11. Acids, Bases, and Salts	10	50.5	2
12. Solution and Crystallization	10	24.5	2
13. Phosphorus. Matches	10	19.	2
14. Useful Metals. Metallurgy	9	63.5	--
15. Photography	9	25.	--
16. Carbon, Its Forms and Uses	9	24.	--
17. Destructive Distillation of Wood and Coal	9	17.5	--
18. Baking Powders, Chemical Action of	8	17.5	--
19. Fuels, Chemical Nature of	6	27.	--
20. Sulfur	4	8.5	--
21. Paints and Oils	4	8.	--
22. Chlorine, Preparation and Properties	4	6.	--
23. Glass, Manufacture of	3	7.	--
24. Lime, Cement, and Clay	3	6.5	--
25. Alloys	3	1.5	--
26. Conservation of Matter, Law of	2	2.5	--
27. Ammonia, Preparation and Properties	2	2.	--
28. Fireproofing and Waterproofing	1	2.5	--
29. Delequescence and Efflorescence	1	1.5	--
30. Phosphorescence, as in fireflies	1	1.	--
31. Flocculation	1	1.	--
32. Distinction between Organic and Inorganic Chemistry	1	1.	--
33. Law of Definite Proportions	1	1.	--
Total pages of topics in Chemistry		632.0	

In HOUSEHOLD ARTS AND SCIENCE.

Topic	*Number of Books*	*Number of Pages*	*Test Topics*
1. Composition of Foods. Carbohydrates, Proteins, Fats	15	118.	--
2. Fuel Value of Foods. Dietary	11	76.5	--
3. Preservation of Foods	7	27.5	--
4. Cleansing of Textiles	6	28.	--
5. Textiles and Clothing	6	17.	--
6. Effect of Cooking on Foods	6	17.	--
7. Soap Making	5	17.5	--
8. Food, Adulteration of	3	15.	--
9. Dyeing	3	5.5	--
10. Household Management	2	10.	--
11. Bread Making	2	9.5	--
12. Flavoring Extracts and Perfumes	2	1.5	--
13. Paper Making	1	.5	--
Total pages of topics in Household Arts and Science		343.5	

In ASTRONOMY.

Topic	*Number of Books*	*Number of Pages*	*Test Topics*
1. The Solar System, Sun and Planets	13	67.	--
2. The Seasons	13	36.5	--
3. The Stars, and Constellations	10	50.5	--
4. The Earth as a Planet	10	36.5	--
5. The Moon. Eclipses	8	30.5	--
6. Time	8	17.5	--
7. Latitude and Longitude	6	20.	--
8. The Tides	4	7.	--
9. Comets	3	3.5	--
10. Meteors	3	2.5	--
Total pages of topics in Astronomy		271.5	

In MISCELLANEOUS TOPICS.

Topic	*Number of Books*	*Number of Pages*	*Test Topics*
1. Value and Method of Science Study	8	40.5	--
2. World Commerce and Transportation	5	41.5	--
3. Man's Relation to Nature	4	12.	--
4. Economic Problems, Wages, Industry, etc.	1	11.5	--
5. Prehistoric Man	1	6.	--
6. Psychology. The Mind	1	3.	--
7. Principles of Civilization	1	3.	--
8. Economy in the Home, General	1	1.5	--
9. Drawing, the Art of	1	1.5	--
Total pages of Miscellaneous Topics		120.5	
Total number of pages classified		6,638.0	

Table II. shows the distribution of each of the science groups in each of the eighteen texts, in each case the sciences being ranked in order. This minute data is recorded for reference, but a more comprehensive appreciation of the status of the sciences may be obtained from the summary of this table. The rank of Physics, as most important in the matter of space devoted to its topics, is indisputable. The deviations of this science from first rank in the texts are almost negligible. The agreement as to the ranks of other sciences is less unanimous, but uniform—that is, the deviations from the median rank are practically the same. Even Physiology, which most greatly varies in the importance assigned to it by different authors, shows a median deviation of only 1.5 ranks either way.

Since the median rank of Biology and Physiography is third in each case, and the deviations are identical, these sciences are tied as to importance. Physiography occurs first in two texts, however, and is recorded above Biology for this reason. Physiology and Chemistry have also the same median rank, but the deviation of Physiology is greater, and toward the higher ranks—a difference which is clearly brought out by the calculation of the least sum, which gives that science a slight advantage.

The treatment accorded to Household Art and Astronomy is decidedly superficial. As expected, neither of these sciences ranks first or second. The small amount of space devoted to Miscellaneous topics is another contradiction of the claim that much of General Science could not be classified under the headings of the more familiar and established branches of scientific knowledge.

TABLE II.

PERCENTAGE COMPOSITION OF GENERAL SCIENCE TEXTS.

Text A. 588 pages.

Science	*Pages*	%
Physics	255.5	43.4
Physiography	143.5	24.4
Physiology	83.5	14.2
Household Art	42.	7.1
Chemistry	25.5	4.3
Biology	23.	3.9
Astronomy	7.5	1.3
Miscellaneous	0.	0.
Unclassified	7.5	1.4

Text B. 370 pages.

Science	*Pages*	%
Physiology	63.5	17.0
Biology	58.	15.7
Physics	50.	13.5
Physiography	36.5	9.9
Household Art	24.	6.5
Chemistry	22.	6.0
Astronomy	19.5	5.3
Miscellaneous	15.5	4.2
Unclassified	81.	21.9

Text C. 302 pages.

Science	*Pages*	%
Physics	74.	24.6
Physiography	73.5	24.3
Biology	67.5	22.3
Physiology	44.	14.6
Chemistry	12.	4.0
Household Art	10.	3.3
Miscellaneous	6.5	2.2
Astronomy	4.	1.3
Unclassified	10.5	3.4

Text D. 395 pages.

Science	*Pages*	%
Physics	107.5	27.3
Biology	69.5	17.5
Physiography	68.5	17.4
Physiology	47.5	12.0
Astronomy	41.5	10.5
Household Art	12.	3.0
Chemistry	11.	2.8
Miscellaneous	6.5	1.6
Unclassified	31.	7.9

Text E. 479 pages.

Science	*Pages*	%
Physics	143.	30.0
Physiography	71.5	14.8
Biology	63.5	13.3
Household Art	61.	12.7
Physiology	58.5	12.2
Chemistry	52.	10.9
Astronomy	4.	.8
Miscellaneous	0.	0.
Unclassified	25.5	5.3

Text F. 294 pages.

Science	*Pages*	%
Physics	89.5	30.4
Physiology	49.5	16.9
Chemistry	24.5	8.3
Biology	17.5	6.0
Astronomy	11.5	3.9
Physiography	8.	2.7
Miscellaneous	3.	1.0
Household Art	0.	0.
Unclassified	90.5	30.8

Text G. 283 pages.

Science	*Pages*	%
Physics	94.	33.3
Physiography	73.5	25.8
Biology	55.5	19.5
Chemistry	20.5	7.2
Astronomy	10.	3.5
Household Art	4.	1.4
Miscellaneous	4.	1.4
Physiology	2.	.7
Unclassified	20.	7.2

Text H. 418 pages.

Science	*Pages*	%
Physics	169.5	40.5
Biology	62.5	15.0
Physiology	52.5	12.6
Physiography	33.	7.9
Household Art	28.5	6.8
Chemistry	26.	6.2
Astronomy	6.	1.4
Miscellaneous	6.	1.4
Unclassified	34.	8.2

Text I. 378 pages.

Science	*Pages*	%
Physics	164.	43.4
Chemistry	87.	23.0
Physiography	54.5	14.5
Miscellaneous	26.	6.9
Household Art	19.	5.0
Biology	18.	4.7
Physiology	3.	.8
Astronomy	0.	0.
Unclassified	6.5	1.7

Text J. 468 pages.

Science	*Pages*	%
Physics	130.	27.9
Physiology	102.5	21.8
Biology	59.	12.6
Chemistry	47.5	10.1
Physiography	46.5	10.0
Household Art	18.5	4.0
Miscellaneous	3.	.6
Astronomy	1.	.2
Unclassified	60.	12.8

Text K. 539 pages.

Science	*Pages*	%
Physics	235.	43.6
Physiology	98.	18.2
Household Art	54.	10.0
Physiography	45.5	8.5
Astronomy	35.	6.5
Chemistry	26.	4.8
Biology	5.5	1.0
Miscellaneous	0.	0.
Unclassified	40.	7.4

Text L. 435 pages.

Science	*Pages*	%
Physics	139.5	32.2
Physiography	64.5	14.7
Biology	60.5	13.9
Chemistry	43.5	10.0
Physiology	42.5	9.8
Household Art	28.5	6.6
Astronomy	24.	5.5
Miscellaneous	6.	1.4
Unclassified	26.	5.9

Text M. 306 pages.

Science	*Pages*	%
Physiography	90.5	29.6
Physics	61.5	20.0
Biology	45.	14.7
Astronomy	31.	10.1
Chemistry	26.5	8.7
Physiology	11.5	3.8
Household Art	2.	.7
Miscellaneous	1.5	.5
Unclassified	36.5	11.9

Text N. 193 pages.

Science	*Pages*	%
Physics	62.5	32.4
Biology	25.5	13.4
Chemistry	24.	12.4
Astronomy	19.5	10.1
Physiology	14.5	7.5
Physiography	9.	4.7
Household Art	7.	3.6
Miscellaneous	2.5	1.3
Unclassified	28.5	14.6

Text O. 295 pages.

Science	*Pages*	%
Physics	91.5	31.0
Physiography	58.5	19.9
Biology	36.5	12.4
Chemistry	35.	11.9
Physiology	26.	8.4
Astronomy	22.5	7.6
Household Art	18.5	6.3
Miscellaneous	7.5	2.5
Unclassified	0.	0.

Text P. 609 pages.

Science	*Pages*	%
Physics	209.5	34.5
Biology	89.5	14.7
Chemistry	77.	12.7
Physiography	70.5	11.6
Physiology	56.5	9.3
Miscellaneous	20.5	3.4
Astronomy	1.	.2
Household Art	0.	0.
Unclassified	84.5	13.6

Text Q. 460 pages.

Science	*Pages*	%
Physiography	258.5	56.2
Biology	70.5	15.3
Physics	62.5	13.6
Astronomy	33.	7.2
Physiology	16.	3.5
Miscellaneous	7.	1.5
Chemistry	6.5	1.4
Household Art	4.	.9
Unclassified	2.	.4

Text R. 430 pages.

Science	*Pages*	%
Physiology	114.5	26.7
Biology	80.5	18.8
Chemistry	56.	13.0
Physics	52.5	12.2
Physiography	51.	11.9
Household Art	10.5	2.4
Miscellaneous	5.	1.2
Astronomy	3.	.7
Unclassified	57.	13.1

TABLE II.—SUMMARY.

Rank of the Sciences in Percentage Composition.

All Texts Included.

Science	*Number of Texts in Which the Science Ranks*								*Least Sum*	*Median Rank*	*Median Dev.*	*Av. Dev.*
	1st	2d	3d	4th	5th	6th	7th	8th				
Physics	14	1	2	1					26	1.	0	.4
Physiography	2	6	2	4	2	2			58	3.	1.	1.2
Biology		7	7	1		2	1		58	3.	1.	1.2
Physiology	2	3	2	2	6	1	1	1	73	4.5	1.5	1.7
Chemistry		1	4	4	3	4	2		83	4.5	1.5	1.3
Household Art			1	2	3	6	3	3	107	6.	1.	1.0
Astronomy				3	4	1	6	4	112	7.	1.	.9
Miscellaneous				1		2	5	10	131	8.	0	.7

CHAPTER IV.

THE ACCEPTABILITY OF GENERAL SCIENCE TOPICS.

THE richness of the field of science renders it very unlikely that there will ever be a recognized list of uniformly acceptable topics such as would be found in Latin grammars, histories, and mathematical texts. On the other hand, a text in General Science which was composed of topics found in no other texts would at once be branded as a freak; a science concerning which no two books agreed as to suitable material would be of questionable value for instruction. It has appeared from the previous tables that authors of General Science texts have agreed in a large measure as to the suitability of certain topics in science, rather than indulging in that diversity which the inexhaustible material would permit. This agreement has not been uniform, of course, with the different sciences; it has been less uniform when the different texts are compared; and even the individual topics are susceptible of quantitative measurement as to their suitability, as evidenced by the space devoted to them in one or more of the eighteen texts. In order to determine this factor for the topics, and from these data to measure the degree of acceptability which characterizes each science and each text, a method of calculating an Acceptability Factor has been devised.

Derivation of the formula

$$\frac{t^2p}{TP} = \text{Acceptability Factor,}$$

where

t = number of texts in which a topic occurs,
T = total number of texts (18 in this study),
p = number of pages devoted to the topic in a certain text,
P = number of pages devoted to the topic in all texts,
these data being recorded in Tables I. and II.

The acceptability of a topic included in t texts compared with that of a topic found in T texts is the ratio $t : T$.

The acceptability of a topic to which p pages are devoted in a certain text compared to the average number of pages devoted to that topic in each of the texts (18 or less) which include it is the ratio p : average, or $p : P/t$.

The real acceptability, all influences being considered, is, therefore, represented by the value

$$\frac{t}{T} \times \frac{p}{\frac{P}{t}} = \frac{t}{T} \times \frac{tp}{P} = \frac{t^2p}{TP}$$

If all texts contained the topic, t/T would equal 1.

If all texts containing the topic contained exactly the same space devoted to it, then no text would give excess or deficient attention to the topic, and tp/P would equal 1.

A perfect acceptability, therefore, would result in a value of unity, which represents the characteristic treatment received by a topic if all authors were exactly agreed as to its importance. It makes no difference whether the topic receives a large or small amount of space, the value obtained is a true measure of the degree to which the topic is uniformly acceptable to General Science authors.

The Acceptability Factor will be greater than 1 for a topic in a certain text which receives marked prominence as to space, and which is included in all, or nearly all, texts.

The Acceptability Factor will be less than 1 for a topic in a certain text which is given little prominence in that text, or which occurs in only a few of the texts.

A text with a high average Acceptability Factor in a certain science contains topics in that science which have been considered important by most of the other authors of General Science texts, and these topics have received space above, or at least only slightly below, the average space for those topics.

A text with a low average Acceptability Factor in a certain science has emphasized topics not considered important by other authors of General Science texts, and has omitted, or superficially treated, the topics which are generally included by the other authors. Depending on the point of view, such a text would be commended for its originality, or criticized as a freak. It is at least *sui generis*.

If a text ranks high or low in its average Acceptability Factor for all sciences, the corresponding general suitability of its topics, as measured by the composite opinions of all authors of General Science texts upon these topics, is indicated.

If a science has a high average Acceptability Factor for the eighteen texts, there is considerable agreement among the authors of General Science texts as to the most characteristic and suitable topics of that science.

If a science has a low average Acceptability Factor for the eighteen texts, there is a disagreement as to the most suitable topics.

Examples. In text K, 13 pages were devoted to a discussion of lenses and the refraction of light. This topic

occurs in 12 books, and covers a total of 45 pages. Substituting in the formula,

$$\frac{12 \times 12 \times 13}{18 \times 45} = 2.311, \text{ the Acceptability Factor,}$$

which indicates that the author of this text considered this topic of over twice the importance assigned to it by the combined judgment of all authors of General Science texts.

In text L, 4.5 pages were assigned to the topic of water and wind power, the topic being mentioned in 10 texts and covering 50 pages. Then substituting in the formula,

$$\frac{10 \times 10 \times 4.5}{18 \times 50} = .500, \text{ the Acceptability Factor,}$$

by which it is shown that this author selected a topic not considered acceptable by all authors, and gave it less than the average amount of space, the topic being rated at one-half the standard value it would have possessed if all the authors had agreed upon its use, and assigned a definite and uniform number of pages to its discussion.

The Acceptability Factor was calculated for each of the 1,557 unit topics of the eighteen texts of General Science. This minute data, although of interest, is exceedingly bulky, and Table III. contains only the following significant values for each text in each science:

1. The number of topics which exceed the standard Acceptability Factor of 1, and the average acceptability of these topics.
2. The number of topics which have an Acceptability Factor below the standard of 1, and the average acceptability of these topics.
3. The total number of topics, and the average acceptability.
4. The sciences are listed in the table in the order of the average acceptability of all their topics in all texts.
5. In a summary the texts are ranked in the order of the average acceptability of all their topics in all sciences, the number of which is given.

If the judgment of the writer be accepted, that an Acceptability Factor of .500 or over indicates a satisfactory agreement as to the suitability of a topic, or if that value as an average for the topics of a text or a science represents a general suitability of the topic selected, it then appears that, with the exception of Household Arts and Zoölogy, there is a fairly well-established agreement among the authors of General Science as to what subject-matter is appropriate. Only six of the texts show a tendency to select

their material far afield. This agreement is more striking because the judgments of the authors have been made independently over a period of many years. General Science, as a whole, cannot be considered as a hodgepodge of unrelated topics selected by irresponsible whims. Diametric attitudes might be taken as to which type of acceptability, high or low, was a characteristic of the best texts—the greater likeness to the more common topics of "special science" in the former case, or the greater freedom from traditional principles and illustrations of these same "special sciences" in the latter type, being each offered as a desirable quality on a General Science text. Whichever argument appeals, the Acceptability Factor furnishes a quantitative measure of the true condition.

TABLE III.

ACCEPTABILITY FACTORS.

PHYSIOGRAPHY. Average of 190 topics in 18 texts, .670
Median, .713

Text	*Excess*		*Deficiency*		*Total*	
	Number	*Average*	*Number*	*Average*	*Number*	*Average*
A	6	2.431	5	.525	11	1.565
B	0	—	12	.356	12	.356
C	3	1.118	8	.615	11	.753
D	3	1.169	7	.578	10	.755
E	4	1.668	8	.285	12	.746
F	0	—	3	.274	3	.274
G	4	1.374	6	.331	10	.748
H	0	—	9	.311	9	.311
I	1	1.656	7	.568	8	.704
J	0	—	13	.387	13	.387
K	2	1.649	3	.641	5	1.044
L	2	1.350	9	.582	11	.722
M	0	—	19	.359	19	.359
N	0	—	4	.248	4	.248
O	1	1.368	15	.319	16	.385
P	4	1.247	5	.688	9	.936
Q	4	2.453	14	.484	18	.924
R	0	—	9	.445	9	.445

PHYSICS. Average of 523 topics in 18 texts, .631
Median, .619

Text	*Excess*		*Deficiency*		*Total*	
	Number	*Average*	*Number*	*Average*	*Number*	*Average*
A	11	2.158	9	.642	20	1.476
B	1	1.333	22	.335	23	.379
C	5	1.097	14	.504	19	.700
D	3	1.160	27	.454	30	.527
E	6	1.486	25	.544	31	.726
F	2	1.160	36	.365	38	.407
G	4	1.271	24	.425	28	.546
H	10	1.392	25	.438	35	.713
I	10	1.794	16	.551	26	1.029
J	2	1.428	42	.405	44	.451
K	12	1.535	24	.446	36	.809
L	2	1.420	37	.530	39	.575
M	0	—	33	.316	33	.316
N	3	1.172	16	.444	19	.663
O	0	—	40	.377	40	.377
P	14	1.461	16	.425	30	.908
Q	2	1.105	19	.414	21	.480
R	4	1.445	7	.479	11	.830

BOTANY. Average of 194 topics in 18 texts, 603
Median, 605

Text	Excess Number	Excess Average	Deficiency Number	Deficiency Average	Total Number	Total Average	Total Botany and Zoölogy Number	Total Botany and Zoölogy Average
A	1	3.052	0	—	1	3.052	1	3.052
B	0	—	12	.373	12	.373	17	.344
C	3	1.264	12	.371	15	.550	18	.506
D	2	1.695	12	.439	14	.618	17	.572
E	5	1.451	8	.255	13	.715	18	.604
F	0	—	7	.251	7	.251	8	.235
G	1	2.195	10	.475	11	.631	13	.636
H	2	1.114	12	.498	14	.686	22	.535
I	0	—	4	.593	4	.593	4	.593
J	0	—	15	.364	15	.364	27	.300
K	0	—	4	.338	4	.338	4	.338
L	1	1.053	13	.333	14	.383	24	.299
M	2	1.311	9	.482	11	.633	15	.528
N	1	1.544	7	.414	8	.555	9	.513
O	1	1.149	11	.286	12	.357	17	.290
P	5	2.184	7	.440	12	1.167	13	1.180
Q	3	1.216	10	.522	13	.682	18	.562
R	4	1.532	10	.411	14	.724	18	.657

CHEMISTRY. Average of 243 topics in 18 texts, .601
Median, .578

Text	Excess Number	Excess Average	Deficiency Number	Deficiency Average	Total Number	Total Average
A	2	1.234	5	.552	7	.747
B	0	—	11	.323	11	.323
C	1	1.173	5	.584	6	.682
D	1	1.192	5	.503	6	.618
E	1	1.123	19	.420	20	.427
F	1	1.194	14	.328	15	.593
G	2	1.396	5	.527	7	.776
H	0	—	12	.583	12	.583
I	9	1.754	11	.434	20	1.028
J	3	1.164	20	.393	23	.493
K	1	1.311	13	.362	14	.430
L	2	1.265	17	.480	19	.562
M	1	1.073	16	.244	17	.293
N	2	1.483	10	.371	12	.556
O	3	1.237	14	.430	17	.573
P	4	2.365	12	.482	16	.970
Q	1	1.210	5	.236	6	.399
R	7	1.395	8	.587	15	.970

PHYSIOLOGY—HYGIENE. Average of 169 topics in 18 texts, .547
Median, .541

Text	Excess Number	Excess Average	Deficiency Number	Deficiency Average	Total Number	Total Average
A	2	2.265	4	.509	6	1.094
B	2	1.057	11	.363	13	.469
C	2	1.232	7	.347	9	.544
D	3	1.157	7	.274	10	.538
E	2	1.515	8	.398	10	.621
F	1	1.022	11	.431	12	.444
G	0	—	1	.255	1	.255
H	3	1.256	6	.502	9	.753
I	0	—	2	.194	2	.194
J	5	1.256	14	.337	19	.581
K	4	1.612	6	.347	10	.854
L	0	—	8	.607	8	.607
M	0	—	7	.185	7	.185
N	0	—	6	.292	6	.292
O	0	—	13	.222	13	.222
P	3	1.555	3	.360	6	.957
Q	0	—	10	.208	10	.208
R	4	1.359	14	.428	18	.634

ASTRONOMY. Average of 78 topics in 17 texts, .524
Median, .509

Text	*Excess*		*Deficiency*		*Total*	
	Number	*Average*	*Number*	*Average*	*Number*	*Average*
A	1	1.928	0	—	1	1.928
B	0	—	6	.501	6	.501
C	0	—	2	.455	2	.455
D	3	1.541	2	.612	5	1.170
E	1	1.028	0	—	1	1.028
F	0	—	6	.273	6	.273
G	1	1.217	2	.198	3	.538
H	0	—	5	.165	5	.165
I	0	—	0	—	0	—
J	0	—	1	.117	1	.117
K	1	1.320	9	.362	10	.458
L	2	1.093	3	.449	5	.717
M	0	—	8	.565	8	.565
N	1	1.051	4	.384	5	.517
O	0	—	10	.344	10	.344
P	0	—	1	.140	1	.140
Q	1	1.370	7	.502	8	.610
R	0	—	1	.771	1	.771

HOUSEHOLD ARTS AND SCIENCE. Average of 69 topics in 16 texts, 464
Median, 260

Text	*Excess*		*Deficiency*		*Total*	
	Number	*Average*	*Number*	*Average*	*Number*	*Average*
A	2	1.824	1	.495	3	1.216
B	0	—	7	.258	7	.258
C	1	1.059	0	—	1	1.059
D	0	—	2	.564	2	.564
E	3	1.067	4	.487	7	.736
F	0	—	0	—	0	—
G	0	—	2	.194	2	.194
H	1	1.112	4	.427	5	.564
I	0	—	2	.516	2	.516
J	0	—	7	.252	7	.252
K	1	3.283	6	.279	7	.708
L	1	1.138	3	.554	4	.700
M	0	—	2	.097	2	.097
N	0	—	5	.120	5	.120
O	0	—	8	.202	8	.202
P	0	—	0	—	0	—
Q	0	—	3	.143	3	.143
R	0	—	4	.262	4	.262

ZOOLOGY. Average of 69 topics in 15 texts, .288
Median, .228

Text	*Excess*		*Deficiency*		*Total*	
	Number	*Average*	*Number*	*Average*	*Number*	*Average*
A	0	—	0	—	0	—
B	0	—	5	.275	5	.275
C	0	—	3	.291	3	.291
D	0	—	3	.364	3	.364
E	0	—	5	.309	5	.309
F	0	—	1	.137	1	.137
G	1	1.043	1	.294	2	.668
H	0	—	8	.265	8	.265
I	0	—	0	—	0	—
J	0	—	12	.218	12	.218
K	0	—	0	—	0	—
L	0	—	10	.183	10	.183
M	0	—	4	.237	4	.237
N	0	—	1	.174	1	.174
O	0	—	5	.126	5	.126
P	1	1.304	0	—	1	1.304
Q	0	—	5	.248	5	.248
R	1	1.000	3	.237	4	.428

MISCELLANEOUS TOPICS. Average of 22 topics in 15 texts, .280
Median, .170

Text	Excess Number	Excess Average	Deficiency Number	Deficiency Average	Total Number	Total Average
A	0	—	0	—	0	—
B	0	—	3	.048	3	.048
C	0	—	1	.208	1	.208
D	0	—	1	.208	1	.208
E	0	—	0	—	0	—
F	0	—	1	.263	1	.263
G	0	—	2	.155	2	.155
H	0	—	2	.246	2	.246
I	1	2.283	0	—	2	2.283
J	0	—	1	.263	1	.263
K	0	—	0	—	0	—
L	0	—	1	.055	1	.055
M	0	—	1	.132	1	.132
N	0	—	1	.143	1	.143
O	0	—	3	.111	3	.111
P	1	1.927	0	—	1	1.927
Q	0	—	1	.234	1	.234
R	0	—	2	.185	2	.185

AVERAGE ACCEPTABILITY FACTOR FOR EACH TEXT.

(ALL TOPICS INCLUDED.)

Text	Number	Average	Text	Number	Average
A	49	1.371	H	99	.580
P	76	.978	Q	85	.551
I	64	.923	L	111	.536
K	86	.695	N	61	.485
R	78	.678	J	135	.426
E	99	.638	F	83	.413
C	67	.625	B	92	.364
D	81	.610	M	102	.356
G	65	.592	O	124	.356

CHAPTER V.

THE SIZE OF UNDIVIDED TOPICS IN GENERAL SCIENCE TEXTS.

ONE of the charges against which General Science has been compelled to defend itself is that of superficiality. The criticisms have been met by alleging a different point of view. If superficiality consists of leaving off the alternate theories, inferences, exceptions to rule, qualifying explanations, and other minutiæ, then perhaps General Science is superficial. But if precise, though brief, explanations of the more important phenomena of Nature, presented in simple, unornamented statements easy of comprehension by the adolescent mind, are considered more suitable in the texts to be placed in the hands of children, then General Science is adequately treated.

The number of pages devoted continuously to a single topic is available from the cards on which the original entries were made in the examination of the eighteen texts (Chapter II.), and will be in multiples of half pages. In a given text not only is the typical size of the continuously treated topics significant, but also the distribution of these sizes above and below the median. Two texts might show the same value for the median size of their topics; but the separate measures of one text might conform closely to this central tendency, while those of the other text varied widely from it. Therefore the upper and lower quartiles are given, also the median deviation (P.E.). These data are set out in Table IV.

These tables show that General Science is presented in the form of small unit topics two or three pages in extent. The highest median is only 7.5 pages, found in the treatment of Physiology in text A. Of the 2,214 continuous topics in the eighteen texts, only 71 are in excess of ten pages and only 14 in excess of twenty pages. The median deviation is rarely over two pages, usually one page or less. Only four texts out of eighteen and only one science (Physiography) contain topics of a median size of three pages or more. It is apparent that the authors of General Science texts are in decided agreement as to this phase of the presentation of their subject-matter.

TABLE IV.

THE SIZE OF TOPICS IN GENERAL SCIENCE TEXTS.

(BY PAGES.)

Text	*Quartiles*	*Physics*	*Physiography*	*Biology*	*Physiology Hygiene*	*Chemistry*	*Household Arts, etc.*	*Astronomy*	*Miscellaneous*
A	3 Q	8.	6.5	—	9.5	2.5	8.	—	
	M	3.5	3.5	11.5	7.5	1.5	5.	7.5	0
	1 Q	2.	2.	—	2.5	1.	3.	—	
	P.E.	2.	2.	5.5	5.	1.	3.	0	
B	3 Q	2.	3.5	3.5	5.	2.5	3.	3.5	5.
	M	1.5	2.5	1.5	3.	1.	1.5	2.5	3.
	1 Q	.5	1.5	.5	1.	.5	.5	2.	1.
	P.E.	.5	1.	1.	2.	.5	1.	.5	2.
C	3 Q	3.	5.	3.	6.5	2.5	—	—	—
	M	2.5	2.	1.5	4.5	1.5	5.	2.	6.5
	1 Q	1.	1.	1.	1.5	.5	—	—	—
	P.E.	1.	1.5	1.	2.5	1.	1.5	1.	0
D	3 Q	3.5	7.	3.5	6.5	2.	—	10.	—
	M	2.	3.5	1.5	3.	1.5	2.	4.5	6.5
	1Q	1.	1.5	1.	2.	1.	—	2.	—
	P.E.	1.	2.	1.	1.5	.5	.5	2.5	0
E	3 Q	4.5	4.5	3.5	5.	2.5	8.	—	
	M	3.	2.	2.5	3.5	1.5	6.5	1.	0
	1 Q	1.5	1.5	1.5	1.5	1.	4.	—	
	P.E.	1.5	1.	1.	2.	.5	2.	0	
F	3 Q	3.	—	2.	4.	2.		3.	—
	M	1.	2.	1.	3.5	1.	0	1.	3.
	1 Q	.5	—	1.	1.5	.5		1.	—
	P.E.	.5	2.	.5	1.	.5		.5	0
G	3 Q	2.5	4.5	4.	—	3.5	—	—	—
	M	1.5	2.5	2.	2.	1.	2.	1.	1.
	1 Q	1.	1.	1.5	—	1.	—	—	—
	P.E.	.5	1.5	.5	0	.5	0	4.	0
H	3 Q	4.5	3.5	3.	7.	2.5	8.5	1.5	—
	M	3.	1.5	2.	4.	1.5	2.5	1.5	3.
	1 Q	1.5	1.	1.5	2.5	1.	1.	.5	—
	P.E.	1.5	.5	1.	2.	.5	1.5	.5	.5
I	3 Q	6.5	6.5	4.	—	4.5	7.5		—
	M	5.	3.	3.	1.5	3.	5.5	0	13.
	1 Q	2.	1.	2.5	—	1.	3.		—
	P.E.	3.	2.	2.	.5	1.5	2.5		10.
J	3 Q	2.5	5.5	2.	4.5	2.	2.	—	—
	M	1.5	2.	1.5	2.5	1.	1.5	1.	3.
	1 Q	1.	1.	.5	1.	1.	.5	—	—
	P.E.	1.	1.	.5	1.5	.5	1.	0	0
K	3 Q	5.	9.	—	5.	1.	3.	2.5	
	M	3.	5.	1.	2.	1.	2.	1.5	0
	1 Q	1.	2.	—	1.	.5	1.	1.	
	P.E.	2.	3.5	.5	1.	.5	1.5	.5	
L	3 Q	4.	7.	2.5	5.5	2.	7.	5.5	—
	M	3.	2.5	2.	3.5	1.5	4.5	4.	6.
	1 Q	2.	1.5	1.	2.	1.	.5	2.	—
	P.E.	1.5	1.	1.	2.	.5	2.5	2.	0
M	3 Q	2.	4.5	2.5	2.5	2.	—	5.	—
	M	1.	2.	1.5	1.5	1.	.5	2.5	1.5
	1 Q	.5	1.5	1.	.5	.5	—	1.	—
	P.E.	.5	1.	.5	1.	.5	.5	1.5	0
N	3 Q	3.5	3.	3.5	2.5	2.	1.5	2.5	—
	M	2.	2.	1.5	2.	1.5	1.	1.5	1.
	1 Q	1.	1.	1.	1.	.5	1.	1.	—
	P.E.	1.	1.5	.5	1.	1.	.5	.5	0

Text	*Quartiles*	*Physics*	*Physiography*	*Biology*	*Physiology Hygiene*	*Chemistry*	*Household Arts, etc.*	*Astronomy*	*Miscellaneous*
O	3 Q	2.5	4.5	1.5	2.5	2.	3.5	2.	—
	M	1.5	1.5	1.	1.5	1.5	2.	1.	3.
	1 Q	1.	1.	1.	1.	1.	1.	1.	—
	P.E.	.5	.5	.5	.5	.5	1.	.5	0
P	3 Q	7.5	9.	7.5	4.5	4.		—	6.5
	M	4.5	4.5	3.	3.5	3.	0	1.	4.
	1 Q	2.	3.	2.	2.5	1.		—	2.
	P.E.	2.5	2.	2.	3.	2.		0	2.
Q	3 Q	3.	10.	4.	2.5	1.	—	2.5	—
	M	2.	4.	2.	1.5	.5	1.	2.5	7.
	1 Q	1.	1.5	1.5	1.	.5	—	1.5	—
	P.E.	1.	2.5	1.5	1.	0.0	0	1.	0
R	3 Q	4.5	9.	5.	9.5	4.	2.5	—	—
	M	1.5	3.5	4.	3.	3.5	1.	3.	2.5
	1 Q	1.	2.	2.	1.5	2.	.5	—	—
	P.E.	1.	2.5	2.	2.5	1.	.5	0	1.
	All Texts								
	3 Q	3.5	5.5	3.	5.	2.5	5.	3.	5.5
	M	2.	3.	1.5	2.5	1.5	2.	2.	3.
	1 Q	1.	1.5	1.	1.5	1.	1.	1.	1.5
	P.E.	1.	2.	.5	1.5	.5	1.5	1.	1.5

All Sciences

Text	A	B	C	D	E	F	G	H	I
3 Q	6.	3.	4.	4.	4.5	3.	3.	3.5	6.5
M	3.	1.5	2.	2.	2.5	1.5	1.5	2.	3.
1 Q	1.5	.5	1.	1.	1.	1.	1.	1.	1.5
P.E.	2.	1.	1.	1.	1.5	1.	.5	1.	2.

Text	J	K	L	M	N	O	P	Q	R
3 Q	2.5	5.	4.	2.5	2.5	2.5	6.5	4.	5.
M	1.5	2.	2.	1.5	1.5	1.5	4.	2.	3.
1 Q	1.	1.	1.	.5	1.	1.	2.	1.	1.5
P.E.	.5	1.	1.	1.	.5	.5	2.	1.	2.

CHAPTER VI.

THE DISTRIBUTION OF SCIENCES IN GENERAL SCIENCE TEXTS

To CARRY out the spirit of General Science—to be truly "general"—the special sciences should be fairly evenly distributed over the pages of each General Science text, indicating that as each topic is developed, the related facts from all sciences are linked together into the unit project. Even a superficial examination of the texts reveals the fact that the lines of "special science" are not obliterated—the marks of the old divisions, like ancient shore lines, may be plainly discerned. It seems to have been impossible to pulverize many hard lumps of physics, physiology, etc.; and there are places where a browsing reader, covering a dozen pages, would think that he had picked up a text on chemistry, physiography, biology, etc.

To quantitatively measure the evenness of distribution which may be characteristic of each special science in each of the eighteen texts, these texts are divided into ten equal portions. Each portion will contain from 0% to 100% of the subject-matter of a particular science in that text. An ideal distribution would be found if 10% of the space allotted to the science should occur in each of the ten portions—in fact, this would obviously be 100% distributed—i. e., as widely distributed as possible. On the other extreme, if all of the discussion of a certain science should be concentrated into one of the one-tenth portions where only 10% of it should be found, it is obvious that only 10% of the distribution is correct.

The arbitrary selection of ten divisions merely gives a convenient and appropriate fractional part; any other portion would have been usable. Smaller divisions would give more refined data, but extreme minutiæ would have been little, if any, more instructive in the tables which have been computed.

Derivation of the formula

$$\frac{100000}{S(\%^2)} = \text{Per Cent of Distribution,}$$

in which $S(\%^2)$ represents the sum of the separate per cents of a science in each of the one-tenth portions of a text.

The Distribution Per Cent of a science in a certain text is a measure not only of the number of different parts into which the science is divided, but also the size of these parts.

The further the per cent of a science in a one-tenth portion of a text deviates from an ideal 10%, the poorer the distribution. These differences are brought out in correct proportion by representing the respective per cents as areas—that is, by plotting the percents on a line and squaring them.

A perfect distribution would be represented by a line divided into ten equal parts, with squares erected on each division, the resulting rectangle having an area of 1000 per cent units, since the base of each square represented 10%.

An imperfect distribution is illustrated by a case chosen at random—the distribution of the science Household Arts in text B.

Distribution of Household Arts in Text B.

Portion of Text.	1	2	3	4	5	6	7	8	9	10	
%	2.1	12.5	0	0	7.4	39.0	26.7	12.5	0	0	
$(\%)^2$	4.4	156.5			54.8	1521.	712.9	156.5			sum 2606.1

A line is divided in the proportion of the per cent of the science which is found in each of the one-tenth portions of the text. A zero per cent of the science in any portion is, of course, represented by a section of line zero points in length. Squares are erected on each of the divisions of the line, and the areas of these squares added.

The portion of the science which is properly distributed is then compared with this area (2606.1), to which it bears some simple ratio. This fraction is the degree of distribution in relation to the ideal distribution of 10% of the science in each one-tenth division of the text. To convert the fraction into percentage, the numerator is multiplied by 100. Substituting in the formula,

$$\frac{100 \times 1000}{2606.1} = 37.9\%,$$ the Per Cent of Distribution of Household Art in Text B.

Proof of the formula. Three other examples will illustrate the working of the formula. Given the distribution of a science as

10% 10% 10% 10% 10% 10% 10% 10% 10% 10%

in the ten portions of a text. Substituting,

$$\frac{100\ 000}{S(\%^2)} = \frac{100\ 000}{1000} = 100\%$$

The answer is obviously correct, as the distribution is perfect.

Given the distribution of a science as

100% 0% 0% 0% 0% 0% 0% 0% 0% 0%

in the ten portions of a text. Substituting,

$$\frac{100\ 000}{S(\%^2)} = \frac{100\ 000}{10000} = 10\%$$

The answer is obviously correct, as only one-tenth of the science is properly placed in one of the ten portions of the text.

Given the distribution of a science as

20% 0% 20% 0% 20% 0% 20% 0% 20% 0%

in the ten portions of a text. Substituting,

$$\frac{100\ 000}{S(\%^2)} = \frac{100\ 000}{2000} = 50\%$$

The answer is correct, as the science has obviously been distributed only one-half as efficiently as it might have been.

Distribution of less than five pages. Since one-half page is the smallest unit recorded in this study, it is impossible to apply this formula to the few cases where less than five pages is devoted to a certain science in a text. To complete the table, a close approximation of the per cent of distribution in such cases is calculated in the following manner. Just as it is possible to distribute 5 pages into ten divisions of one-half page each, 4.5 pages may be divided into nine such portions, 4 pages into eight portions, etc. If the total amount of a science present in the text is four pages, and is concentrated into one-tenth of the text, when it might have been distributed in eight of these portions (one-half page in each), its distribution is evidently 12.5% of the best that was possible. If the science is found in two of the one-tenth portions, the distribution is 25%, etc.

This principle will be illustrated by a table of the full list of possible distributions of a science with two pages, and another with two and one-half pages of space in a certain text.

Pages	2	2.5
Half-pages	4	5
Half-page value	25%	20%

No. of Divisions	*Distribution*	*Per Cent of Distribution*	*No. of Divisions*	*Distribution*	*Per Cent of Distribution*
1	100	25%	1	100	20%
2	75-25	50%	2	80-20	40%
2	50-50	50%	2	60-40	40%
3	50-25-25	75%	3	60-20-20	60%
4	25-25-25-25	100%	3	40-40-20	60%
			4	40-20-20-20	80%
			5	20-20-20-20-20	100%

It is apparent that these percentages fairly represent the degree of distribution in comparison with the most perfect distribution possible in each case of from one-half to four and one-half pages of a science in a text. The few Distribution Per Cents in Table V. which it was necessary to calculate by this method are all indicated by a sign (*).

The Per Cents of Distribution, and data from which they have been computed, are recorded in Table V. for each science in each text. The texts are ranked in the order of the average Per Cent of Distribution for all the sciences; the sciences are ranked in each text in the order of their respective Per Cents of Distribution. A summary shows the general rank of the sciences in all texts as to distribution.

It appears that the authors of General Science have found it least difficult to scatter the subject-matter of Physics over the pages of their texts, linking the phenomena of that science with the topics of the others. The distribution of Physics in Text K (80.1%) is the highest found for any science in any text. But the average rank for the distribution of Physics (52.4%) greatly exceeds that of the next highest science, Physiography (33.5%), showing that in this and the remaining sciences a condition of real "general" distribution is not even approached. This is not due to any purely accidental value for the averages calculated; for when the distributions for the sciences in each text are averaged, a remarkable uniformity of treatment is disclosed. The extreme range between Text N, 34.8% average distribution, and Text R, 22.8% average distribution, is only 12%. The grand average of 29.7%, therefore, closely represents the general distribution in all texts, showing that no author has radically departed from the established method of grouping the fields of science under the traditional headings. A widely scattered, "general" distribution may not be the chief desideratum of a General Science text; it may not be even one of the more important principles in the selection and arrangement of its subject-matter; but claims of the advantages which General Science texts and General Science courses possess over the texts and courses of "special science" due to this wide distribution have been repeatedly made, and it has been interesting to determine to what extent, both in the individual texts and in the sciences of each text, these claims are valid.

TABLE V.

The Distribution of General Science Topics.

1. Text N. 193 pages. Average Distribution, 34.8%

Science:	1. %	2. %	3. %	4. %	5. %	6. %	7. %	8. %	9. %	10. %	*Distribution* %
	Divisions										
Physics	0	12.	23.2	3.2	8.8	8.8	0	0	29.6	14.4	50.8
Chemistry	0	12.5	2.1	29.2	22.9	20.8	0	0	0	12.5	47.1
Physiology	0	0	0	24.1	14.1	13.8	34.6	3.4	0	0	40.0
Miscellaneous	40	0	0	0	0	0	0	0	60	0	*40.0
Biology	0	4.	0	0	10.	17.9	51.2	13.9	0	4.	30.4
Household Art	0	21.4	0	0	0	0	0	42.9	0	35.7	28.0
Physiography	0	0	0	33.3	0	0	0	55.6	0	11.1	23.6
Astronomy	71.8	10.3	12.8	0	0	0	0	0	0	5.1	18.3

2. Text P. 609 pages. Average Distribution, 34.1%

Science:	1. %	2. %	3. %	4. %	5. %	6. %	7. %	8. %	9. %	10. %	*Distribution* %
	Divisions										
Physics	3.4	14.5	17.3	7.9	21.3	24.9	10.6	0	0	0	56.5
Astronomy	0	100.	0	0	0	0	0	0	0	0	*50.0
Chemistry	3.5	29.8	22.0	0	0	0	0	42.5	.6	.6	30.5
Biology	0	0	0	0	0	0	3.4	17.9	44.7	34.	28.6
Physiology	0	0	0	35.7	0	0	0	0	22.4	41.9	28.6
Miscellaneous	0	0	0	0	41.7	9.7	48.6	0	0	0	23.8
Physiography	61.1	0	2.	5.6	0	0	0	31.3	0	0	2.10
Household Art	0	0	0	0	0	0	0	0	0	0	—

3. Text K. 539 pages. Average Distribution, 33.9%

Science:	1. %	2. %	3. %	4. %	5. %	6. %	7. %	8. %	9. %	10. %	*Distribution* %
	Divisions										
Physics	7.3	10.9	18.3	4.8	4.1	4.9	13.1	18.4	8.8	9.4	80.1
Physiology	2.	0	0	4.6	13.2	33.3	20.4	2.	0	24.5	42.9
Chemistry	0	3.8	42.3	28.8	15.4	1.9	0	3.8	3.8	0	34.4
Physiography	48.4	43.9	0	3.3	0	0	0	4.4	0	0	23.3
Household Art	0	0	0	50.9	42.6	6.5	0	0	0	0	22.4
Biology	0	0	0	27.2	9.	63.8	0	0	0	0	20.4
Astronomy	0	2.7	0	0	0	0	1.8	0	84.2	11.3	13.8
Miscellaneous	0	0	0	0	0	0	0	0	0	0	—

4. Text H. 418 pages. Average Distribution, 33.3%

Science:	1. %	2. %	3. %	4. %	5. %	6. %	7. %	8. %	9. %	10. %	*Distribution* %
	Divisions										
Physics	1.7	11.2	15.1	8.	22.6	17.5	18.	3.5	0	2.4	62.9
Physiology	19.1	19.1	0	7.5	0	17.2	17.2	9.4	0	10.5	62.4
Household Art	12.3	0	40.4	26.3	0	0	0	0	21.	0	34.4
Biology	7.2	0	2.8	0	0	4.	0	8.8	48.8	28.5	29.8
Chemistry	38.5	42.3	0	11.5	7.7	0	0	0	0	0	28.8
Miscellaneous	58.1	0	0	0	0	0	0	0	0	41.9	19.4
Physiography	0	0	0	31.8	0	0	0	68.2	0	0	17.7
Astronomy	0	0	0	0	0	0	0	0	0	100.	10.0

5. Text E. 479 pages. Average Distribution, 33.2%

Science:	1. %	2. %	3. %	4. %	5. %	6. %	7. %	8. %	9. %	10. %	*Distribution* %
	Divisions										
Physiology	0	13.2	22.8	0	27.	6.	6.9	16.4	0	6.9	54.8
Physics	20.3	1.7	0	0	24.1	24.5	24.5	4.2	.7	0	45.1
Chemistry	1.9	24.	17.3	36.6	0	10.6	0	4.8	4.8	0	42.1
Household Art	0	38.6	30.3	31.1	0	0	0	0	0	0	29.5
Physiography	6.7	0	7.5	0	0	0	2.2	44.	38.1	2.2	28.6
Biology	0	1.6	0	11.8	1.6	3.2	0	0	12.6	69.2	19.6
Astronomy	0	0	0	0	0	0	0	0	100.	0	*12.5
Miscellaneous	0	0	0	0	0	0	0	0	0	0	—

6. Text O. 295 pages. Average Distribution, 31.8%

Science:	1. %	2. %	3. %	4. %	5. %	6. %	7. %	8. %	9. %	10. %	Distribution %
Physics	20.3	18.1	9.4	26.3	8.8	8.3	0	0	4.4	4.4	58.8
Chemistry	21.4	14.3	0	8.6	31.4	27.2	1.4	0	5.7	0	50.9
Household Art	0	13.5	0	0	0	18.9	0	5.4	18.9	43.3	35.7
Physiology	19.2	0	0	0	0	7.7	0	0	28.9	44.2	31.0
Physiography	0	0	4.3	0	23.9	11.1	49.6	11.1	0	0	30.3
Biology	0	0	0	0	0	5.9	0	59.4	34.7	0	21.0
Astronomy	0	15.5	73.3	15.5	0	0	0	0	0	0	17.0
Miscellaneous	0	0	0	0	0	0	0	0	0	100.	*10.0

7. Text J. 468 pages. Average Distribution, 31.2%

Science:	1. %	2. %	3. %	4. %	5. %	6. %	7. %	8. %	9. %	10. %	Distribution %
Physics	28.4	13.1	10.8	26.2	13.8	0	0	.8	0	47.5	50.8
Astronomy	0	0	0	100.	0	0	0	0	0	0	*50.0
Physiology	0	7.8	0	0	2.8	0	0	24.5	41.5	23.4	34.0
Household Art	0	2.8	0	0	33.3	0	0	30.6	0	33.3	31.6
Chemistry	0	30.1	40.6	0	27.	0	0	0	0	2.3	30.6
Biology	0	1.8	.9	3.5	0	10.1	67.4	16.0	0	0	20.3
Miscellaneous	100.	0	0	0	0	0	0	0	0	0	*16.7
Physiography	0	1.2	17.4	0	2.4	79.	0	0	0	0	15.4

8. Text B. 370 pages. Average Distribution, 30.8%

Science:	1. %	2. %	3. %	4. %	5. %	6. %	7. %	8. %	9. %	10. %	Distribution %
Physiography	0	0	24.7	34.2	0	13.7	12.3	5.5	2.7	6.9	45.5
Physics	0	0	16.	28.	29.	13.	0	0	0	14.	44.5
Household Art	2.1	12.5	0	0	7.4	39.	26.7	12.5	0	0	37.9
Chemistry	11.9	0	7.1	4.8	28.6	42.8	0	4.8	0	0	34.8
Biology	0	6.9	2.6	0	.9	0	21.5	22.4	45.7	0	32.2
Physiology	44.3	37.1	7.8	0	2.3	0	8.6	0	0	0	23.7
Miscellaneous	0	0	19.4	0	0	6.4	0	74.2	0	0	16.8
Astronomy	0	0	0	0	7.7	0	0	0	0	92.3	11.7

9. Text M. 306 pages. Average Distribution, 30.2%

Science:	1. %	2. %	3. %	4. %	5. %	6. %	7. %	8. %	9. %	10. %	Distribution %
Household Art	0	0	0	0	0	0	0	0	75.	25.	*50.0
Physiography	0	0	2.3	14.4	2.3	20.6	23.8	29.9	6.7	0	46.7
Physics	0	32.1	37.	19.9	10.2	.8	0	0	0	0	34.4
Miscellaneous	0	100.	0	0	0	0	0	0	0	0	*33.3
Biology	0	1.1	0	0	0	0	11.1	0	45.5	42.3	25.1
Chemistry	0	7.1	7.1	0	64.4	21.4	0	0	0	0	21.2
Physiology	0	0	0	21.7	0	8.7	0	0	0	69.6	18.5
Astronomy	88.7	9.7	0	0	0	0	1.6	0	0	0	12.5

10. Text C. 302 pages. Average Distribution, 29.9%

Science:	1. %	2. %	3. %	4. %	5. %	6. %	7. %	8. %	9. %	10. %	Distribution %
Physics	20.9	7.4	0	20.9	20.3	20.3	6.8	3.4	0	0	55.2
Physiography	14.3	25.	0	0	15.	0	28.6	17.1	0	0	50.5
Physiology	0	0	11.4	27.3	0	25.	0	0	36.3	0	35.5
Biology	0	0	27.4	1.5	0	0	0	23.	4.1	43.9	31.1
Chemistry	0	41.6	58.4	0	0	0	0	0	0	0	19.5
Miscellaneous	0	0	0	0	0	61.6	38.4	0	0	0	18.9
Astronomy	75.	0	0	0	0	0	0	25.	0	0	*16.0

11. Text L. 435 pages. Average Distribution, 28.5%

Science:	1. %	2. %	3. %	4. %	5. %	6. %	7. %	8. %	9. %	10. %	*Distribution* %
Physics	12.9	21.6	16.2	15.8	19.	14.4	0	0	0	0	58.4
Chemistry	0	15.1	25.5	2.5	0	31.2	26.7	0	0	0	38.9
Physiography	0	0	.8	29.3	17.	1.5	35.5	15.9	0	0	37.5
Biology	0	4.9	0	0	0	0	8.3	52.9	33.1	.8	25.0
Physiology	0	0	15.3	0	2.4	14.1	0	1.2	0	67.	20.2
Household Art	0	0	0	0	0	0	0	3.5	45.6	50.9	17.8
Astronomy	100.	0	0	0	0	0	0	0	0	0	10.0
Miscellaneous	0	0	0	0	0	0	0	0	100.	0	10.0

12. Text G. 283 pages. Average Distribution, 28.4%

Science:	1. %	2. %	3. %	4. %	5. %	6. %	7. %	8. %	9. %	10. %	*Distribution* %
Physics	6.9	2.7	17.	4.3	28.7	17.5	0	20.2	2.7	0	52.2
Physiography	15.3	27.2	8.5	21.1	0	0	27.9	0	0	0	44.1
Chemistry	0	26.9	0	0	0	34.1	0	34.1	4.9	0	32.6
Biology	0	0	0	15.5	0	6.6	0	0	33.5	44.4	29.7
Physiology	0	0	0	100.	0	0	0	0	0	0	*25.0
Astronomy	20.	0	0	0	0	10.	70.	0	0	0	18.5
Household Art	0	0	0	0	0	0	0	0	100.	0	*12.5
Miscellaneous	100.	0	0	0	0	0	0	0	0	0	*12.5

13. Text F. 294 pages. Average Distribution, 26.9%

Science:	1. %	2. %	3. %	4. %	5. %	6. %	7. %	8. %	9. %	10. %	*Distribution* %
Physics	8.4	21.2	15.1	11.2	9.5	16.2	14.5	4.5	0	0	68.7
Chemistry	21.4	7.9	23.5	0	37.7	6.	0	3.9	0	0	39.3
Physiology	0	0	0	0	0	1.	0	7.	47.5	44.5	23.3
Astronomy	69.5	0	0	0	0	0	30.5	0	0	0	17.3
Miscellaneous	100.	0	0	0	0	0	0	0	0	0	*16.7
Biology	0	0	0	5.7	0	2.8	0	91.5	0	0	11.8
Physiography	0	0	0	93.8	0	0	6.2	0	0	0	11.3
Household Art	0	0	0	0	0	0	0	0	0	0	—

14. Text I. 378 pages. Average Distribution, 26.7%

Science:	1. %	2. %	3. %	4. %	5. %	6. %	7. %	8. %	9. %	10. %	*Distribution* %
Physics	8.4	2.	0	0	0	10.	22.8	.7	22.9	23.2	56.9
Physiography	0	9.2	2.7	22.	40.4	23.8	0	0	1.8	0	36.0
Chemistry	1.1	23.6	47.7	4.7	3.5	5.8	0	12.7	0	1.1	30.6
Biology	0	0	0	22.2	55.6	13.9	0	8.3	0	0	25.9
Physiology	0	66.7	0	0	0	0	0	33.3	0	0	*16.7
Household Art	0	0	5.3	94.7	0	0	0	0	0	0	11.1
Miscellaneous	100.	0	0	0	0	0	0	0	0	0	10.0
Astronomy	0	0	0	0	0	0	0	0	0	0	—

15. Text Q. 460 pages. Average Distribution, 26.6%

Science:	1. %	2. %	3. %	4. %	5. %	6. %	7. %	8. %	9. %	10. %	*Distribution* %
Physiography	0	8.5	9.5	14.6	0	2.5	16.3	15.2	18.2	15.2	69.4
Physics	22.	37.2	24.4	14.	0	0	2.4	0	0	0	37.6
Biology	0	0	1.4	2.8	49.7	37.6	0	0	0	0	25.2
Household Art	0	0	0	0	25.	75.	0	0	0	0	*25.0
Physiology	0	0	0	0	62.5	37.5	0	0	0	0	18.8
Chemistry	0	15.4	84.6	0	0	0	0	0	0	0	13.5
Astronomy	85.1	0	0	0	0	0	10.5	0	0	4.4	13.5
Miscellaneous	0	0	0	0	0	0	0	100.	0	0	10.0

16. Text A. 588 pages. Average Distribution, 26.5%

Science:	*Divisions* 1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	*Distribution*
	%	%	%	%	%	%	%	%	%	%	%
Physics	16.9	11.	22.5	9.6	0	10.2	0	0	7.1	22.7	59.6
Physiography	9.7	2.5	0	21.7	37.6	10.5	0	12.2	5.8	0	45.9
Physiology	0	0	0	0	0	9.	10.8	41.3	38.9	0	29.3
Household Art	0	0	0	0	0	23.8	64.3	11.9	0	0	20.4
Chemistry	0	98.	0	0	0	2.	0	0	0	0	10.4
Biology	0	0	0	0	0	0	100.	0	0	0	10.0
Astronomy	0	0	0	0	0	0	0	0	0	0	—
Miscellaneous	0	0	0	0	0	0	0	0	0	0	—

17. Text D. 395 pages. Average Distribution, 25.0%

Science:	*Divisions* 1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	*Distribution*
	%	%	%	%	%	%	%	%	%	%	%
Physics	19.6	5.	4.4	16.5	17.4	32.	5.	0	0	0	48.7
Physiology	0	0	35.9	2.1	27.3	0	0	0	21.	13.7	37.5
Physiography	13.9	25.6	0	16.	1.5	0	0	43.	0	0	33.9
Biology	0	1.4	25.9	.7	0	0	0	4.3	21.6	46.1	30.3
Astronomy	10.8	0	0	0	4.8	0	78.4	6.	0	0	15.9
Miscellaneous	0	0	0	84.6	15.4	0	0	0	0	0	13.4
Chemistry	0	100.	0	0	0	0	0	0	0	0	10.0
Household Art	0	0	0	0	0	0	0	0	100.	0	10.0

18. Text R. 430 pages. Average Distribution, 22.8%

Science:	*Divisions* 1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	*Distribution*
	%	%	%	%	%	%	%	%	%	%	%
Physiology	0	0	1.3	0	0	0	8.7	26.6	31.9	31.5	35.8
Biology	0	.6	0	0	26.7	45.4	27.3	0	0	0	28.4
Physiography	0	3.8	5.7	53.6	36.9	0	0	0	0	0	23.3
Physics	64.5	11.2	6.5	12.2	0	0	0	0	2.8	2.8	22.3
Chemistry	0	51.8	48.2	0	0	0	0	0	0	0	20.0
Household Art	0	0	0	0	0	0	28.6	66.7	0	4.7	18.9
Miscellaneous	30.	0	0	0	0	0	70.	0	0	0	17.2
Astronomy	0	0	0	100.	0	0	0	0	0	0	*16.7

TABLE V.—*Continued.*

RANK OF THE SCIENCES IN DISTRIBUTION.

ALL TEXTS INCLUDED.

Science	*Number of Texts in Which the Science Ranks* 1st	2d	3d	4th	5th	6th	7th	8th	*Least Sum*	*Median Rank*	*Median Dev.*	*Av. Dev.*
Physics	13	3	1	1					26	1.	0	.4
Physiology	2	3	5	1	5	1	1		65	3.	1.5	1.4
Physiography	2	5	3	1	2		4	1	71	3.	1.5	2.
Chemistry		4	5	1	5	2	1		71	3.5	1.5	1.4
Biology		1	1	7	3	6			84	4.5	.5	.9
Household Art	1		3	4	1	4	1	4	94	6.	2.	1.8
Astronomy		2		1	1	1	7	6	116	7.	1.	1.2
Miscellaneous				2	1	4	4	7	121	7.	1.	1.

AVERAGE AND MEDIAN DISTRIBUTIONS FOR THE SCIENCES.

ALL TEXTS INCLUDED.

Science	—*Distribution Per Cent*— *Average*	*Median*
Physics	52.4%	57.7%
Physiography	33.5%	32.1%
Physiology	32.2%	29.7%
Chemistry	29.7%	30.6%
Household Art	24.8%	21.4%
Biology	24.7%	25.2%
Astronomy	18.4%	14.9%
Miscellaneous	17.9%	15.1%

CHAPTER VII.

CORRELATIONS BETWEEN THE SCIENCES AS TO VARIOUS PHASES OF THEIR TREATMENT IN GENERAL SCIENCE.

CERTAIN questions now arise in connection with the great inequalities in the treatment which the different sciences receive in General Science—for example, the marked predominance of Physics as to space and distribution compared with the decidedly inferior standing of Astronomy, one of the oldest, and Household Arts, one of the newest of sciences. Is there any fundamental connection between any two sciences which causes them to rise and fall together in their ranks? Or do certain sciences receive prominence at the expense of certain others? It has been claimed that Physics and Chemistry are a closely coördinated pair—that Biology and Physiology, Physiography and Astronomy, also Household Arts and Physics, show strong relationships. It has likewise been claimed that Physics and Biology, Physiography and Biology, Physiography and Household Arts, and possibly some other pairs, are to some extent antagonistic, or competitive, and that where a General Science text might have an adequacy or an excess of one, the other would receive deficient treatment.

Such relationships may be most accurately shown by computing the correlations between the sciences in pairs, using a formula which takes into account not only the ranks, but also the quantities involved in each measure of a distribution of ranks. Pearson's Coefficient of Correlation is used to show the relationships set out in the following tables.[1]

CORRELATION BETWEEN THE SCIENCES AS TO SPACE IN THE TEXTS.

In comparing the rank and quantity of each science as to space in the eighteen texts with each other science, 36 coefficients of correlation may be worked out, eight of them being identities. (Correlation, +1.)

Strong positive correlation would indicate a "pairing" of the two sciences, exerting mutual influence over each other's rank. Any author who gave a large space to one would give a proportionally large space to the other, and vice versa.

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[1] Pearson's formula for the Coefficient of Correlation,

$$r = \frac{S(xy)}{\sqrt{S(x^2)} \cdot \sqrt{S(y^2)}}$$

in which x and y represent the respective deviations from the median of the distribution. See Alexander, Carter: "School Statistics and Publicity," page 185.

Strong negative correlation would indicate antagonism between the two sciences, and an inverse ratio as to the space received.

Weak correlation would indicate the lack of any fundamental relationship between the two sciences, the ranks and quantities of each science being independent of the other.

In Table VI. there are 36 correlations between pairs of sciences, eight of them identities (+1.), fifteen positive, thirteen negative. Most of the values are low, only the correlations between Physics-Chemistry (+.517) and Physics-Household Arts (+.590) being sufficiently strong to indicate a pairing—a rise and fall together as to space in the individual texts. In respect to all other pairs, the absence of any general underlying principles of coördination between the sciences in determining the amount of space they are given in General Science texts is demonstrated.

TABLE VI.

CORRELATION BETWEEN THE SCIENCES AS TO THE SPACE GIVEN TO EACH IN THE EIGHTEEN TEXTS.

Science	*Physics*	*Physiography*	*Biology*	*Physiology*
Physics	+1.	+.091	—.277	+.341
Physiography	+.091	+1.	+.167	+.207
Biology	—.277	+.167	+1.	+.106
Physiology	+.341	+.207	+.106	+1.
Chemistry	+.517	+.185	—.074	—.040
Household Art	+.590	+.234	—.312	+.385
Astronomy	—.057	—.363	—.252	—.061
Miscellaneous	+.065	—.115	+.123	—.264

Science	*Chemistry*	*Household Art*	*Astronomy*	*Miscellaneous*
Physics	+.517	+.590	—.057	+.065
Physiography	+.185	+.234	—.363	—.115
Biology	—.074	—.312	—.253	+.123
Physiology	—.040	+.385	—.061	—.264
Chemistry	+1.	+.173	—.264	+.790
Household Art	+.173	+1.	+.061	—.309
Astronomy	—.264	+.061	+1.	—.172
Miscellaneous	+.790	—.309	—.172	+1.

CORRELATION BETWEEN THE SCIENCES AS TO PER CENT OF DISTRIBUTION IN THE TEXTS.

The remarkable uniformity in the average Per Cent of Distribution of the sciences for each of the eighteen texts (29.7%, with average deviation of only 2.9%) may be due either to uniform distribution of each science throughout all of the texts, or to widely varying, but compensating, per cents of distribution. The question then arises: Is distribution a quality inherent in a text—that is, does an author who distributes a certain science widely show proportionally good distribution in the other sciences, or vice versa? Or, comparing the sciences directly, is the wide

distribution of a certain science, such as Physics, usually accompanied by the wide distribution of another science, such as Chemistry?

If the answers to these questions are affirmative, strong positive values would be obtained in determining the correlation of pairs of sciences by Pearson's formula. If, on the other hand, the wide distribution of one science, such as Physics, is obtained in most texts at the expense of the concentration of some other science, such as Biology, strong negative correlations would indicate the fact.

In Table VII. there are 36 correlations between pairs of sciences—eight identities (+1.), fifteen positive, and thirteen negative. The only positive value above .4 is in the correlation between Biology-Miscellaneous (+.500)—a relationship without significance. A very moderate indication of pairing is shown in the correlation between Physics-Chemistry (+.356). Stronger negative correlations are found in the relation of Physiography to several other sciences—Physics (—.368), Physiology (—.441), Chemistry (—.486), Astronomy (—.368). It appears that in those texts where the other sciences were widely scattered, Physiography was through some necessity concentrated, and vice versa.

The values of these correlations are too low to admit of strong positive interpretations. The close agreement of the averages for the texts is evidently due to compensating values for the different distributions which each science received in the eighteen texts. The present status as to distribution is clearly one of individualism. If in future texts the effective spreading of the topics of each special text throughout all portions of the book should become recognized as a necessary principle, the correlations will become positive and significant. If the tendency should favor larger groups of all recognized "special sciences," there would also be strong positive correlations. But if it should happen that Chemistry becomes more widely distributed throughout all texts because of its intimate relations to each of the other sciences, while Biology becomes more concentrated for the sake of coherence, then strong negative correlations will be obtained between this pair. Such general tendencies would be clearly revealed by correlations, but their absence has been demonstrated in the data of Table VII.

TABLE VII.

Correlation Between the Sciences as to the Per Cent of Distribution in the Eighteen Texts.

Science	*Physics*	*Physiology*	*Physiography*	*Chemistry*
Physics	+1.	+.106	—.368	+.356
Physiology	+.106	+1.	—.441	+.120
Physiography	—.368	—.441	+1.	—.486
Chemistry	+.356	+.120	—.486	+1.
Biology	—.316	-.063	+.139	—.051
Household Art	—.126	-.215	+.184	+.136
Astronomy	—.090	+.072	—.368	+.053
Miscellaneous	—.373	—.088	—.143	+.107

Science	*Biology*	*Household Art*	*Astronomy*	*Miscellaneous*
Physics	—.316	—.126	—.090	—.373
Physiology	+.063	+.215	+.072	—.088
Physiography	+.139	+.184	—.368	—.143
Chemistry	—.051	+.136	+.053	+.107
Biology	+1.	+.072	—.002	+.500
Household Art	+.072	+1.	—.166	+.178
Astronomy	—.002	—.166	+1.	+.264
Miscellaneous	+.500	+.178	+.264	+1.

Correlation Between the Number of Pages and the Per Cent of Distribution of Each Science.

One of the chief criticisms directed against General Science texts has been that the "hobbies" of the authors were evident—that large sections of some "special" science were included bodily in the text, violating the principles of generalness which is supposed to characterize General Science. The defense has been that if the space devoted to a science was large in the aggregate, it was because numerous topics had been inserted wherever they were worth while—that extensive use of the particular science was due to its broad and varied relationships to the problems of daily life. The exceedingly scant and superficial attention paid to other sciences being also criticized, this has been explained on the grounds that adequate treatment of all sciences is impossible—that the author has selected topics from the special fields in the proportion in which they most properly fit into the definite plan of his text, and thus the wisest possible choice from each science has been made.

When the total amount of space devoted to the topics of each science is determined, the amount varies greatly in the different texts. Are the large totals due to the use of a greater number of small topics, or to larger masses of the "special" science? Is the prominent rank of a certain science as to space in General Science due to more extensive or more intensive treatment? Strong positive correlations between Space and Distribution of a science would indicate that the prominent treatment was characterized by the use

of many rather than large topics, giving possible grounds for the charge of superficiality. Strong negative correlations would show that large space was usually poorly distributed, and a basis for the accusation of "hobbies" would be furnished.

In Table VIII. the correlations are positive in six sciences, negative in two, all but one being of low value. This exception is in the science Biology (+.536), of which it is characteristic that the texts giving the science most space tend to distribute it most thoroughly. This tendency, however, cannot be characteristic of General Science as a whole, or the correlations in each science would have been more strongly positive.

When the relationship of the sciences in the individual texts is considered by rank alone, it is seen that the science which ranks highest as to space usually is given the highest rank in distribution, and a science treated in a small number of pages is likely to be found in one or two groups. Correlating the ranks of the sciences as to per cent of space occupied and per cent of distribution in each text separately by Spearman's Rank Order Formula,[1] Table IX. shows perfect agreement in Text A, with positive correlations in all other texts, most of them exceedingly strong. The distribution which a certain science receives in one text is not a function of the importance of that science in General Science as a whole, but to its space in that text only. Neither is there any definite relationship between the actual number of pages a science may include in a text and its distribution; the agreement is in rank only. This further emphasizes the conclusion that no matter how much unity of plan an individual author may embody in his text, his arrangement is individual and original, and General Science as a whole is not unified.

TABLE VIII.

CORRELATION BETWEEN THE NUMBER OF PAGES AND PER CENT OF DISTRIBUTION IN EACH SCIENCE.

Science	*Correlation*	*Science*	*Correlation*
Biology	+.536	Physiology	+.350
Chemistry	+.264	Miscellaneous	+.256
Household Art	+.249	Physics	+.049
Astronomy	—.146	Physiography	—.202

[1] Spearman's Rank Order Formula for Correlation, $r=1-\frac{6S(d^2)}{n(n^2-1)}$

See Alexander, Carter: "School Statistics and Publicity," page 184.

TABLE IX.

CORRELATION BETWEEN THE RANKS OF THE SCIENCES AS TO PER CENT OF SPACE AND PER CENT OF DISTRIBUTION IN EACH TEXT.

SPEARMAN'S RANK ORDER FORMULA USED.

Text	*Correlation*	*Text*	*Correlation*
A	+1.00	B	+.33
C	+.88	D	+.81
E	+.47	F	+.86
G	+.83	H	+.71
I	+.76	J	+.28
K	+.78	L	+.93
M	+.09	N	+.43
O	+.52	P	+.55
Q	+.62	R	+.90

CORRELATION BETWEEN THE SCIENCES AS TO ACCEPTABILITY FACTORS IN THE TEXTS.

Is the proper selection of subject-matter inherent in a text? That is, if an author selects the topics of one science well, does he likewise exercise good discrimination in the case of the other sciences? If an author decides to be original and unconventional in his choice of the subject-matter he presents in one science, will his tendency be transferred to the other sciences included in his text?

Uniformly good selection, uniformly poor selection, or uniformly mediocre selection of two sciences in all or nearly all texts would be indicated by a strong positive correlation between the ranks of their Acceptability Factors when computed by Pearson's formula. But if good selection in one science was uniformly accompanied by poor selection of another science in all or nearly all texts, a strong negative correlation would be secured.

Table X. shows 36 correlations—eight identities (+1.), twenty-five positive, and three negative. In these negative values the Miscellaneous group constitutes one of the pair; hence these correlations are not significant. Of the twenty-five positive values, ten are strongly so, over +.500, and five moderate, between +.400 and +.500. The low positive values are in Miscellaneous and in Chemistry, except where the latter correlates fairly high with Physics (+.472).

These values show a very strong tendency for a conservative text to make equally appropriate selections of the topics of each important science—a poor, or bizarre, text to be uniformly unconventional. The former tendency is the principal one, for twelve of the eighteen texts have Acceptability

Factors above .500. (Table III.) If General Science were a hodgepodge of unrelated topics, the Acceptability Factors would be exceedingly low and the correlations close to zero.

TABLE X.

CORRELATION BETWEEN THE SCIENCES AS TO ACCEPTABILITY FACTORS.

ALL TEXTS INCLUDED.

Science	*Physiography*	*Physics*	*Biology*	*Chemistry*
Physiography	+1.	+.715	+.651	+.171
Physics	+.715	+1.	+.808	+.472
Biology	+.651	+.808	+1.	+.327
Chemistry	+.171	+.472	+.327	+1.
Physiology	+.595	+.643	+.566	+.201
Astronomy	+.621	+.684	+.716	+.055
Household Art	+.490	+.427	+.485	+.118
Miscellaneous	+.050	+.212	+.171	+.674

Science	*Physiology*	*Astronomy*	*Household Art*	*Miscellaneous*
Physiography	+.595	+.621	+.490	+.050
Physics	+.643	+.684	+.427	+.212
Biology	+.566	+.716	+.485	+.171
Chemistry	+.201	+.055	+.118	+.674
Physiology	+1.	+.379	+.435	—.121
Astronomy	+.379	+1.	+.581	—.488
Household Art	+.435	+.581	+1.	—.104
Miscellaneous	—.121	—.488	—.104	+1.

PART II.

CHAPTER VIII.

THE ADAPTABILITY OF GENERAL SCIENCE IN THE LAST THREE GRAMMAR GRADES. TEST TOPICS.

WITH very few exceptions, General Science courses are intended for the use of pupils in their first high-school year. Of the eighteen General Science texts examined in the spring of 1919, only one was admittedly designed for the grades. It is a fact, however, that in many places a General Science course is given in one of the years which constitute the Junior High School, seventh or eighth grade, one of the simpler texts being presumably used.

It is by no means a generally accepted principle that General Science should be placed exclusively in the High School—that it is unsuited for the grades. In the great reorganization which world events are forcing upon the methods and curricula of schools, in which the demand for a useful knowledge of environment is drowning out the defensive arguments for courses of abstract and remoter value, more than one voice speaks for an earlier introduction to Nature by instruction in her simpler principles given to children even in the lowest grades.

Certain important principles in the selection of subject-matter for science instruction in the grades may only be determined by experiment. There is excellent agreement among authors of General Science texts as to the suitability of a large number of the topics of the five principal sciences (Table III.) ; but could the same subject-matter be used in the grades, even in simple form? For example, could the meteorological causes of winds and storms (17 texts), the types of energy, momentum, inertia, etc. (15 texts), the botany and chemistry of photosynthesis (16 texts), the chemical composition of the atmosphere (16 texts), be explained to sixth-grade children in a manner which would really result in their assimilation and understanding of the principles involved?

For science instruction in the grades, may topics from the five principal sciences be used in equal amounts? May they be used in the same proportion as they now occur in General Science, or in some other proportion suggested by experiment?

May suggestions be obtained from experimental evidence as to the assimilability, or average amount of possible understanding, which children will show to each of the five

principal sciences in the grades, to determine if this assimilability is uniform?

If assimilability is not uniform, which science should predominate in the instruction in each grade? What are the relative amounts of the other sciences which may be acceptably included in that grade? If a certain science, such as Chemistry, is not suitable for instruction in the sixth grade, in which grade may its topics be profitably included?

These and many other questions have prompted the study which follows:

Selection of the Test Topics.

Table I. shows that the subject-matter of General Science has been principally obtained from five sciences. It was planned to select 25 important and characteristic topics from each of these sciences, choosing only those which occur in a clear majority of the texts. In Physics there are more than 25 topics each of which is found in ten or more texts; in the other sciences there are less than 25 such topics. The Zoölogy section of Biology contains no topic included in ten texts; but to avoid eliminating the subject altogether, five leading topics were chosen from Zoölogy, which, added to 20 topics from Botany, fills out the quota for Biology.

In choosing the particular fact of science upon which the statements of the "test topic" were to be based, a minute division of each topic was made by examining the half-page cards from which the data of Table I. and others had been compiled. These subtopics were recorded, and ranked according to the number of texts in which each was treated. For example, the first topic of Physics, Transfer of Heat (18 texts), is composed of the subtopics Convection (16 texts), Conduction (15 texts), Types of Furnaces (15 texts), Radiant Heat (14 texts), Practical Ventilation (11 texts), and nine other items of minor rank. Since but one subtopic is to be selected, and that must be the one most prominently treated, the choice falls upon the principles of Convection, which is discussed in the largest number of texts. In a similar manner the most important subtopic of each of the 25 most highly ranked topics in Physics was selected.

In the other sciences, where less than 25 topics were included in a majority of the texts, it was necessary to select two or more subtopics from the topics which had the greatest number of pages. For example, in Physiography three subtopics each were chosen from the first three topics, since

these contained more pages than the others, and two subtopics from each of the remaining eight topics, making 25 in all. In determining which three subtopics were most prominent in the topic—that of Humidity and Precipitation (17 texts), for example—the component items were found to be General Cause of Humidity (17 texts), Rain (17 texts), Snow (16 texts), Clouds (16 texts), Dew (11 texts), Frost (11 texts), and nine other minor ones. The three subtopics chosen were Rain and Snow, Clouds and Fog, Dew and Frost, since these were clearly predominant and occur in a majority of the 17 texts mentioning Humidity.

In a similar manner, all of the 125 "test topics," 25 from each of the five principal sciences, were selected. The number of test topics chosen from each important topic of a science is recorded in a column in Table I. These subtopics are those which rank highest in their respective topics; the topics are the most important of their respective sciences; all (except five in Biology, from the Zoölogy division) occur in a clear majority of the eighteen texts. It is believed that this method has resulted in the selection of test topics thoroughly characteristic of each science, each topic representing the most favorable judgment of more than a majority of the authors of General Science texts as to its fitness to be presented as a part of the instruction in his text.

Following a special study of the texts as to language and treatment of each selected topic, the test which was to be put into the hands of the children was prepared, consisting of a little folder of four pages fastened together.

Page 1.

TO EACH BOY AND GIRL:

This is a game to see how well you can remember. Here are the rules:

1. DO NOT TURN ANY PAGE OVER, OR LOOK AT IT, UNTIL THE TEACHER TELLS YOU TO DO SO.
2. WHEN THE TEACHER TELLS YOU TO, WRITE ANSWERS TO THE QUESTIONS.
3. ON ONE PAGE THERE IS SOMETHING TO READ. TRY TO REMEMBER IT IF YOU CAN.
4. DO NOT LOOK *AHEAD*, AND DO NOT LOOK *BACK*, AT ANY PAGES.

Page 2.

A question designed to discover whether the child already has a knowledge of the principles of the test topic. This question was direct, simple, and usually covered one point only. If answered correctly, it would be evident that the

child possessed some apperceptive basis for the further consideration of the particular topic involved. If answered incorrectly, it would appear that the child either had no previous conception of the subject or was unable to express one. The data obtained from the answers to this question were expected to be a measure of the foundation of previous knowledge upon which instruction in General Science in the grades might be built.[1]

Page 3.

A direct statement, in which the facts and principles of the test topic were set forth as clearly and simply as possible. While a strict composite of the discussions in the ten or more texts was impossible, the statement was carefully worded after a study of the language of each text. Illustrations accompanied this paragraph in thirty-five instances.

Page 4A.

One or more direct questions, calling for the specific information given on the preceding page. A correct answer would be evidence that the child has been capable of understanding the subject-matter of the statement; and the further inference is not unreasonable that similar statements, equally characteristic of the science and of approximately the same degree of complexity, might also be assimilated by the child. An incorrect answer, or no answer, might indicate that the topic was apparently too complicated for the child's understanding, and that he would probably have difficulty, or fail completely, in the assimilation of similar topics in that science.

Page 4B.

One or more questions, based on the specific information of the statement on page 3, but involving a further step of reasoning along some closely related line. A correct answer would indicate that the child not only understood the topic, but was able to apply its principles to the solution of another problem such as might be next propounded by text or teacher in ordinary recitation. An incorrect answer would warrant the conclusion that the principles of the statement, even if understood by the child, were in isolated position in his mind, and not sufficiently correlated with his apperceptions to be of practical value.

[1] For a similar test of certain phases of Chemistry in beginning classes, see Webb, H. A., "A Preliminary Test in Chemistry," Journal of Educational Psychology, Vol. X., No. 1, page 36 (January, 1919).

Lines for the grade, name, and age of the child headed each sheet, so that they could be identified if separated.

Special effort was made to avoid questions which could be answered by mere "yes" or "no," or in which the choice of one alternative without explanation would suffice, the laws of chance predicting correct answers in 50 per cent of such cases. The use of certain words, familiar enough to adults, but possibly strange to the child, such as "explain," "illustrate," "describe," "discuss," etc., was discarded in favor of the simpler phrases, "Tell about it," "What is," "Why is," etc.

It is fully realized that in some instances the wording of the statement and questions might have an undue influence for correctness or incorrectness of the answers. This condition is minimized in two directions, however: first, the language, in practically every case, is essentially that of one or more texts, simplified as to words or difficult phrases, or at least is as typical of all texts as a close study was able to determine; second, in twenty-five test topics for each science a few statements or questions of more than the average difficulty would probably be compensated by a few of abnormal simplicity. The combined results for all twenty-five test topics would thus be a fair measure for the science as a whole.

With each package of test topics sent out, letters to teachers explaining the spirit of the test were inclosed, and also a page of specific directions. The number of minutes which were to be allowed a child for writing answers to each question, and for studying the statement, was determined by some preliminary experiments in the Demonstration School of George Peabody College for Teachers. The object was to give sufficient time for even slow pupils to finish, and the indicated periods were found to be ample.

DIRECTIONS TO THE TEACHER.

(This test is for the last three grammar grades only.)

In order that there may be uniformity in the methods by which this test is given, it is requested that the teacher in charge of the pupils use the method and wording below:

Step 1.

(The teacher should see that each child has a pencil, and that the teacher has a watch or can see a clock.)

Teacher (to children): "Girls and boys, here is a new game. I am going to have placed on each desk some sheets of paper, face downward, and you must not touch or handle them until I tell you to."

(Have the sets, four small pages each, quietly distributed, face downward.)

Step 2.

Teacher (to children): "Now turn the whole thing over, and let us read the rules together." (The reading should be done in concert, or by the teacher plainly and with emphasis, the children reading silently.) The rules—

TO EACH BOY AND GIRL:

This is a game to see how well you can remember. Here are the rules:

1. DO NOT TURN ANY PAGE OVER, OR LOOK AT IT, UNTIL THE TEACHER TELLS YOU TO DO SO.
2. WHEN THE TEACHER TELLS YOU TO, WRITE ANSWERS TO THE QUESTIONS.
3. ON ONE PAGE THERE IS SOMETHING TO READ. TRY TO REMEMBER IT IF YOU CAN.
4. DO NOT LOOK *AHEAD*, AND DO NOT LOOK *BACK*, AT ANY PAGES.

Step 3.

Teacher (to children): "Now turn the first page over. Write your grade, name, and age on the first line. Then answer the question or questions below if you can. I will tell you to stop in just two minutes. If you finish before that time, sit quietly, and do not turn any pages."

(Allow exactly *two* minutes for the writing.)

Step 4.

Teacher (to children): "Now turn the page over. You must not turn it back again. Write your grade, name, and age. Read what is written on this page, and try to understand and remember it. Do not turn the page until I tell you to. You will have two minutes to study."

(Allow exactly *two* minutes for study.)

Step 5.

Teacher (to children): "Now turn the page, and do not turn it back again. Write your grade, name, and age on the first line. Answer the questions if you can. I will stop you in four minutes; but if you finish before, sit perfectly still, and do not change what you have written."

(Allow exactly *four* minutes for this writing.)

(The papers should now be promptly collected without alteration.)

TEST TOPICS IN PHYSICS.[1]

1. *Page 2.*

Question 1. Why, in winter, is it always colder in a room near the floor than near the ceiling?

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[1] A complete set of the test topics in the mimeographed form as sent out may be secured by any interested person on application to the author.

Page 3. CONVECTION CURRENTS. (Illustrated.)

Statement: Whenever air becomes warmer, it expands; and because this makes it lighter, it rises. Cold air contracts, is heavy, and falls. In a room the warm air goes to the ceiling, while cold air comes in along the floor.

The same thing is true of water. If a bucket of water is heated, the warm water goes to the top, and cold water to the bottom.

This movement of air or water, due to a difference in temperature, is called "convection."

* * *

Page 4.

Question 2. Tell why warm air or water rises, and cold air or water falls.

Question 3. Why do the boilers of big factories have such tall chimneys? Why would not a short chimney do as well?

2. THERMOMETERS. (Illustrated.)
3. THE PRESSURE OF AIR. (Illustrated.)
4. THE KINDS OF ENERGY.
5. THE THREE STATES OF MATTER. (Illustrated.)
6. HOW HEAT IS MEASURED.
7. THE LEVER. (Illustrated.)
8. MAGNETS. (Illustrated.)
9. SPECIFIC GRAVITY.
10. HOW SUCTION IS CAUSED BY AIR PRESSURE. (Illustrated.)
11. HOW LIGHT IS REFLECTED. (Illustrated.)
12. THE INCLINED PLANE. (Illustrated.)
13. THE FORCE OF GRAVITATION.
14. THE SPECTRUM COLORS, OR RAINBOW. (Illustrated.)
15. ELECTROMAGNETS. (Illustrated.)
16. THE BOILING AND FREEZING POINTS OF WATER.
17. HOW ICE IS MADE.
18. THE BENDING OF LIGHT RAYS. (Illustrated.)
19. HOW COAL HAS BEEN MADE.
20. HOW ELECTRIC DYNAMOS AND MOTORS WORK.
21. HOW A STEAM ENGINE WORKS.
22. EXPANSION OF SUBSTANCES WHEN HEATED.
23. THE NATURE OF LIGHT.
24. ARTIFICIAL LIGHTING.
25. THE NATURE OF SOUND.

TEST TOPICS IN PHYSIOGRAPHY.

1. *Page 2.*

Question 1. Rain, or snow, is water falling from the sky. How does the water get up into the sky?

* * *

Page 3. RAIN AND SNOW.

Statement: As warm air blows across oceans and lakes, it gathers much water vapor from their surfaces. The winds blow this moisture over the land in the form of clouds. The tiny drops of water which form the cloud gradually make larger drops by running together, and fall to the ground as rain.

If the moisture in the cloud freezes before it starts to fall, it comes to the ground as snow.

Page 4

Question 2. Where does the water in the sky come from, and how does it turn into rain? Why does the water in the sky sometimes turn to snow instead of rain?

Question 3. Why do big clouds sometimes go sailing by without any rain, and why do they at other times pour rain upon the earth?

2. CLOUDS AND FOG.
3. DEW AND FROST.
4. HIGH AND LOW PRESSURE OF AIR.
5. A "COLD WAVE."
6. WIND BELTS OF THE EARTH.
7. THE KINDS OF SOIL.
8. HOW SOIL HAS BEEN MADE.
9. WHAT SOIL IS MADE OF.
10. FORECASTING THE WEATHER.
11. THE WORK OF THE UNITED STATES WEATHER BUREAU.
12. HOW CAVES HAVE BEEN FORMED.
13. SPRINGS AND WELLS.
14. HOW A STREAM SORTS OUT ROCKS OF DIFFERENT SIZES.
15. THE CUTTING OF VALLEYS. (Illustrated.)
16. DELTAS AND FLOOD PLAINS. (Illustrated.)
17. THE IRRIGATION OF DESERT LANDS.
18. SWAMPS AND DRAINAGE.
19. HOW COAL HAS BEEN MADE.
20. WHAT COAL IS MADE OF.
21. CLIMATE.
22. THE EFFECT OF LAKES AND OCEAN ON CLIMATE.
23. IGNEOUS ROCKS, ROCKS THAT HAVE BEEN MELTED.
24. HOW LIMESTONE IS FORMED.
25. THE CAUSE OF LIGHTNING AND THUNDER.

TEST TOPICS IN BIOLOGY.

1. *Page 2.*

Question 1. Where do trees get the material to make wood out of while they are growing?

* * *

Page 3. THE FORMATION OF STARCH IN PLANT LEAVES.

Statement: Leaves are the food makers for the plant. Two substances unite in the leaves: (1) The carbon dioxide gas from the air; (2) water coming through the roots and up the stem.

These two substances unite in the leaves to form starch. This can only happen while the sun is shining. At night the starch which has been made during the day is carried to all parts of the plant. This is what makes the plant grow.

* * *

Page 4.

Question 2. Tell how a plant manufactures starch in its leaves. What becomes of the starch after it is made?

Question 3. If a plant is placed in a dark cellar, will it grow much? Tell exactly why.

2. THE GREEN SUBSTANCE IN LEAVES.
3. THE FUNGUS PLANTS. MOLDS.
4. THE YEAST PLANT. (Illustrated.)

5. HOW FLOWERS MAKE FRUITS. (Illustrated.)
6. THE PARTS OF A FLOWER. (Illustrated.)
7. THE PURPOSE OF ROOTS. (Illustrated.)
8. THE FORMS OF ROOTS. (Illustrated.)
9. THE NITRIFYING BACTERIA. (Illustrated.)
10. GOOD AND BAD GERMS.
11. HOW SEEDS ARE SCATTERED.
12. HOW SEEDS GROW. (Illustrated.)
13. THE STEMS OF TREES. (Illustrated.)
14. TREES AND THEIR USES. (Illustrated.)
15. GERMS, OR BACTERIA. (Illustrated.)
16. HOW GERMS, OR BACTERIA, REPRODUCE. (Illustrated.)
17. THE PURPOSE OF LEAVES.
18. HOW LEAVES HELP THE PLANT.
19. HOW PLANTS USE THE AIR.
20. HOW PLANTS USE WATER.
21. THE LIFE HISTORY OF INSECTS.
22. THE BODY OF A TRUE INSECT. (Illustrated.)
23. THE KINDS OF ANIMALS.
24. THE LIFE HISTORY OF A FROG. (Illustrated.)
25. THE SIMPLEST ANIMAL, AN AMEBA. (Illustrated.)

TEST TOPICS IN PHYSIOLOGY.

1. *Page 2.*

Question 1. How do catching diseases, like measles, get from one person to another?

Page 3. THE CAUSE OF DISEASE.

Statement: All catching diseases are due to tiny germs, which may live in our nose, our throat, our lungs, our intestines, our blood, and in other parts of our body. These germs get into our body when we do various things which are not healthy, such as drinking impure water, eating food on which flies have walked, drinking from cups that other people use, etc. In fact, if we carelessly handle anything that sick people have used, the germs from these sick persons may get into our bodies and give us the disease.

Page 4.

Question 2. How does one person catch a disease from another? What are the best ways to keep from catching diseases?

Question 3. Do flies ever do us any harm? Why should we try to keep flies away from our food?

2. WHERE GERMS ARE FOUND IN THE BODY.
3. TOXINS AND ANTITOXINS.
4. HOW GERMS MAY BE KILLED.
5. HOW WATER IS PURIFIED.
6. THE IMPURITIES IN WATER.
7. PURE WATER TO DRINK.
8. INSECTS WHICH CARRY DISEASE.
9. FLIES AND TYPHOID FEVER.
10. THE CAUSE OF MALARIA.
11. THE GASES IN OUR LUNGS.
12. HOW WE BREATHE. (Illustrated.)
13. THE STRUCTURE OF OUR LUNGS. (Illustrated.)
14. THE DIGESTION OF FOOD IN THE MOUTH.
15. HOW FOOD IS DIGESTED IN OUR INTESTINES.
16. HOW FOOD IS DIGESTED IN OUR STOMACH.

17. DEFECTS OF THE EYE. FAR-SIGHT AND NEAR-SIGHT.
18. HOW POOR LIGHT HURTS THE EYES.
19. HOW THE EYES SEE. (Illustrated.)
20. THE HARMFULNESS OF ALCOHOL.
21. THE HARM OF PATENT MEDICINES.
22. HOW TOBACCO HARMS THE BODY.
23. OUR HEART. (Illustrated.)
24. WHAT THE BLOOD IS MADE OF.
25. THE BLOOD VESSELS.

TEST TOPICS IN CHEMISTRY.

1. *Page 2.*

Question 1. Why must fire in a stove have plenty of air before it will burn?

Page 3.

Statement: Whenever anything burns, it unites with oxygen gas from the air. Since only about one-fifth of the air is oxygen, a substance would burn more vigorously in a bottle of pure oxygen than it would in air.

Some substances, such as paper, wood, coal, etc., unite with oxygen very rapidly. These burn easily, and with much flame. Other things, such as iron, lead, and other metals, unite with the oxygen of the air very slowly, and become covered with rust. Rusting and burning are similar processes, except that burning is a more rapid union with oxygen than rusting. In pure oxygen a hot iron wire would not rust, but would catch fire and burn.

Page 4.

Question 2. In what way is the burning of wood and the rusting of iron alike? In what ways are burning and rusting different?

Question 3. Does the oxygen which we breathe from the air have anything to do with the warmth of our skin? Tell about it.

2. FLAMES. KINDLING POINTS.
3. THE GASES OF THE AIR.
4. THE AIR IS A MIXTURE.
5. THE PROPERTIES OF OXYGEN.
6. THE PREPARATION AND PROPERTIES OF OXYGEN.
7. CARBON DIOXIDE GAS.
8. CARBON DIOXIDE AS A FIRE EXTINGUISHER.
9. WHAT WATER IS MADE OF.
10. THE COMPOSITION OF WATER.
11. ATOMS AND MOLECULES.
12. ELEMENTS, MIXTURES, AND COMPOUNDS.
13. THE PROPERTIES OF HYDROGEN.
14. PREPARATION AND PROPERTIES OF HYDROGEN.
15. THE HARDNESS OF WATER.
16. HOW WASHING SODA HELPS IN WASHING.
17. PHYSICAL AND CHEMICAL CHANGES.
18. PHYSICAL AND CHEMICAL ACTIONS.
19. HOW NITROGEN IS PREPARED FROM THE AIR.
20. ACIDS, BASES, AND SALTS IN THE HOME.
21. ACIDS, BASES, AND SALTS.
22. HOW CRYSTALS ARE FORMED. (Illustrated.)
23. HOW THINGS DISSOLVE IN WATER.
24. THE PROPERTIES OF PHOSPHORUS.
25. HOW MATCHES ARE MADE.

CHAPTER IX.

DISTRIBUTION AND SAMPLING OF THE TEST TOPICS.

THE value of a study such as the one here undertaken increases with the number of individuals to whom the test is applied. In the present instance, circumstances made it necessary that all the grading, tabulating, etc., be done by the writer; consequently the number of tests had to be confined within reasonable limits. On the other hand, it was realized that a sufficient number must be used to insure fair sampling. A goal of ten thousand replies was decided upon, which, if fairly distributed among the five sciences, would give approximately 2,000 tests for each.

Letters were sent to 120 Superintendents of Schools in towns of not more than 10,000 or less than 5,000 population, as given in the Educational Directory for 1918. Sixty-two superintendents agreed to distribute the material to their teachers for use. The supply of test pamphlets, 125 different kinds, was thoroughly mixed and mingled, and approximately 19,000 of them sent to these superintendents. Forty of them returned a total of 9,819 sets. The names of the cities and of the superintendents, to each of whom the writer feels personally indebted, follow:

City and State—Superintendent	*Number of Pupils in Each Grade*			
	5th	6th	7th	8th
ALABAMA				
Bessemer, L. L. Vann	149	164	103	
Florence, F. T. Appleby	40	56	86	
Gadsden, W. C. Dodson	148	97	147	
Huntsville, R. C. Johnston	47	52	30	38
Talladega, D. A. McNeil	51	51	45	
ARKANSAS				
Helena, E. B. Tucker		55	49	28
Jonesboro, J. P. Womack		21	14	10
FLORIDA				
Miami, R. E. Hall		92	164	81
GEORGIA				
Albany, R. E. Brooks	73	73	72	
Americus, J. E. Mathis		76	67	40
ILLINOIS				
Carbondale, A. R. Boone		40	59	29
Granite City, L. P. Frohardt		115	116	113
Normal, C. F. Miller		40	45	49
INDIANA				
Alexandria, F. W. Stoler		65	57	34
Bedford, E. W. Montgomery		96	80	67
Goshen, James Wilkinson		101	80	91
KENTUCKY				
Paducah, Ralph Yakel		343	398	336
Paris, Lee Kirkpatrick		65	45	33
Richmond, W. D. Bridges		35	40	8

City and State—Superintendent	*Number of Pupils in Each Grade*			
LOUISIANA				
Alexandria, C. C. Hensen	142	194	146	
Morgan City, L. A. Law		61	46	
MARYLAND				
Sykesville, Miss Adda Mai Cummings		11	12	15
MISSISSIPPI				
Yazoo City, H. M. Ivy	31	24	36	
MISSOURI				
Carthage, W. C. Barnes		40	138	81
NORTH CAROLINA				
Concord, A. S. Webb	144	113	80	
Greensboro, Frederick Archer	28	26	30	
OHIO				
Barberton, U. L. Light		91	98	74
Troy, C. W. Cookson		80	86	68
OKLAHOMA				
Alva, Albert W. Fanning		69	71	30
Chickasha, William F. Ramey		106	102	103
Shawnee, H. G. Faust		126	124	210
TENNESSEE				
Bristol, R. B. Rubins		80	73	49
Clarksville, A. J. Smith		96	93	44
Columbia, B. F. Harris		52	44	27
Nashville (Glenn School), H. C. Weber		21	26	35
Peabody Demonstration School, J. S. Tippett		67	60	22
TEXAS				
Tyler, T. H. Shelby	141	125	159	
VIRGINIA				
Charlottesville, James G. Johnson	172	131	119	
Fredericksburg, E. F. Birkhead	73	81	53	
WEST VIRGINIA				
Morgantown, F. T. Pyle		37	134	165

In several of the States the "last three grammar grades" are numbered 5th, 6th, and 7th; in others, 6th, 7th, and 8th. Two methods of grouping their answers are possible—either considering the 5th, 6th, 7th grades in one set of schools as equivalent to the 6th, 7th, 8th grades of the other schools, or considering the 6th and 7th grades of both groups as equivalent and treating the 5th and 8th grades separately. An attempt was made to ascertain whether the curricula of the two types of schools would indicate which of the two methods was most appropriate, but expressions on the point were conflicting and largely a matter of opinion. It was decided, therefore, to avoid the responsibility of assuming either side of the argument to be correct, and to record both sets of the last three grammar grades separately. It will not be difficult, if any one so desires, to combine the data of a table for any two grades considered equivalent.

For purposes of identification, the 6th and 7th grades in the 5-6-7 grouping will be followed by the letter "x" in all future references; the 6th and 7th grades in the 6-7-8 grouping will be followed by the letter "r." These letters were derived from the words "xtra" and "regular," which were first used to keep the records of the two types separate.

ANALYSIS OF THE SAMPLING.

The 9,819 test sets returned represented exceedingly fair sampling, as indicated by the following tables:

Grand Total, by Grades.

5	1239	6r	2072
6x	1201	7r	2305
7x	1122	8	1880

The higher grades in each group show slightly fewer replies, as expected.

Grand Total, by Sciences.

If the distribution had been perfect, each science would be represented by 1,964 answers. The number of answers received, and the deviation from this average, is recorded:

Science	*No. Answers*	*Dev.*
Physiology	2032	+ 68.
Physiography	2001	+ 37.
Physics	1957	—7.
Chemistry	1933	—31.
Biology	1896	—68.

The count shows a remarkable uniformity. The slight deviation is almost perfectly symmetrical. The extreme range out of nearly two thousand answers is only 136. The various deviations from the average of 1,964 average only 43, or 2.2%.

Totals in Each Science, by Grades.

Science	*5*	*6x*	*7x*	*Science*	*6r*	*7r*	*8*
Physiology	291	229	214	Physiology	439	486	373
Physiography	231	245	235	Physiography	433	466	391
Physics	257	239	224	Physics	421	446	370
Chemistry	230	260	218	Chemistry	384	464	377
Biology	230	228	231	Biology	395	443	369
Average	248	240	224	Average	414	461	376
Av. Deviation	21	10	7	Av. Deviation	20	15	6

These data show that the tests were distributed with great uniformity to the separate grades, and that there is no marked excess or deficiency of answers in any science or in any grade. The fairness of the sampling seems to be thoroughly demonstrated.

ANSWERS TO INDIVIDUAL TEST TOPICS.

In each one of the six grade groups, children answered questions related to five sciences, which were presented under twenty-five test topics. Thus there are $6 \times 5 \times 25 = 750$ separate and distinct question groups under which the results are recorded. Each of these 750 units constitutes the number of answers received for one test topic of one science in one grade. There is no reason to expect that each unit group would contain the same number of answers; on the other hand, by the laws of probability, there should be a normal distribution curve for the number of unit groups which would successively contain answers ranked in order from zero on upward.

That the normal distribution is closely approximated is shown by the data in Table XI. The five divisions of the curve show the following distribution:

Question groups answered by—

5 Students or Less	*6-10 Students*	*11-15 Students*	*16-20 Students*	*20 or More Students*	*Total*
96	184	226	144	100	750
12.80%	24.53%	30.13%	19.20%	13.33%	99.99%

The curve is slightly skewed toward the left, or zero end. The median number of answers is 13—that is, half the unit groups include 13 or less answers and half include 13 or more answers. The quartiles are in the 8 and 16 group, which again calls attention to the slight skew toward the lower ranks. The curve shows three mildly prominent modes at the 9, 12, and 15 groups.

The efforts to secure a perfectly random distribution seem to have been entirely successful.

TABLE XI.

DISTRIBUTION OF 750 UNIT QUESTION GROUPS ACCORDING TO THE NUMBER OF STUDENTS ANSWERING THEM.

Number of Answers	*Unit Groups Involved*	*Number of Answers*	*Unit Groups Involved*	*Number of Answers*	*Unit Groups Involved*	*Number of Answers*	*Unit Groups Involved*
0	4						
1	4	11	35	21	25	31	4
2	15	12	52	22	20	32	1
3	25	13	46	23	16	32	2
4	20	14	45	24	7	34	2
5	28	15	48	25	6	35	1
6	28	16	43	26	4	36	1
7	27	17	28	27	4	37	1
8	38	18	29	28	4	above 37	0
9	50	19	22	29	1		
10	41	20	22	30	1		

CHAPTER X.

ANALYSIS OF THE MARKS.

THE letters A, B, and C were used in marking the tests. "A" represents a correct answer in which the student displays a reasonable understanding of the topic, and expresses the idea in a manner which would be acceptable to the average teacher. "B" represents a decidedly inferior answer, a hazy conception evidenced by faulty or incomplete expression, leaving doubt as to whether there is really an appreciable understanding. The germ of the idea is recognizable, however. "C" represents an incorrect answer, or no answer at all. Since the time allowed for writing the test was proved to be generous, the lack of an attempt is reasonably interpreted as inability on the part of the student to answer. In a few cases, where, in spite of strict prohibitions found in the instructions, the answers were obviously copied from the statement on page 3 of the pamphlet, a mark of "C" was given.

METHOD OF GRADING.

Each of the 29,457 questions were individually marked by the writer. They were taken in the unsorted order, just as received from the superintendents. In this way the possibility of the mind getting into a certain "track" in marking a large number of identical questions was avoided—a condition in which reasonable variations in answers might not be properly judged. Each mark was of necessity a matter of separate decision. Admitting the unquestioned fact that in a certain per cent of the cases a mark of A would be given where a mark of B or C was better justified, the laws of probability would equalize the matter in the large number of judgments involved with the compensating error of substituting B or C for A in an approximately equal number of cases. Further, the conclusions of this study are not based upon the minute data such as would be influenced by a small per cent of erroneous judgments. The grading was done almost continuously day after day, and thus the point of view remained reasonably constant throughout the entire time. No tabulations of any kind were made until after all the grading was completed. Thus it was impossible to tell the tendencies which were developing or to receive any information which might bias the judgments in any way.

The question had been asked of each superintendent as to whether the children had received any previous instruction in General Science, the object being to discover whether

any schools in which the subject was taught had been accidentally included in the list. Only one small group of 30 pupils in the eighth grade of one school had elected such a course under an option. The answers of these pupils were compared with the marks of 30 others in the same school and grade, and no appreciable difference was noted. These test papers were then included in the general distribution.

NUMERICAL COUNT OF MARKS.

The numerical count of the marks for each of the three questions, the objects of which have been previously explained, is recorded in Table XII. Certain general tendencies are roughly indicated by these results—that the number of A's and C's are approximately equal, and either is more than one and one-half times the number of B's. The A's are more numerous in the higher grades, the C's more numerous in the lower grades, as expected. Question 1, on Previous Knowledge, receives roughly 2½ times as many C's as A's, while Question 2, on Direct Assimilation, has about 2½ times as many A's as C's. In Question 3, on the Power of Application, the C's predominate, but are only 20% in excess.

As to the separate sciences, the most noticeable feature is the decided difficulty which was experienced with Chemistry, which in all three questions is markedly deficient in A's and received C's in excess.

In all sciences the reactions of the children were least favorable toward Question 1, Previous Knowledge, which received fewest A's and most C's; and most favorable toward Question 2, Direct Assimilation, with most A's and fewest C's.

TABLE XII.

NUMERICAL COUNT OF THE MARKS.

	A's Question				*B's Question*				*C's Question*			
Grade	*1*	*2*	*3*	*Total*	*1*	*2*	*3*	*Total*	*1*	*2*	*3*	*Total*
5	164	312	281	857	223	376	264	863	852	451	694	1997
6r	351	961	614	1926	452	619	441	1512	1296	492	1017	1778
6x	231	578	385	1194	223	350	259	832	747	273	557	1577
7r	558	1375	920	1853	538	575	433	1546	1209	355	952	1516
7x	294	704	469	1467	278	278	248	804	550	140	405	1095
8	608	1370	944	2922	491	355	349	1195	781	155	587	1523
Total	2206	5400	3613	11219	2205	2553	1994	6752	5408	1866	4212	11486

	A's Question				*B's Question*				*C's Question*			
Science	*1*	*2*	*3*	*Total*	*1*	*2*	*3*	*Total*	*1*	*2*	*3*	*Total*
Physiology	591	1306	1117	3014	574	440	456	1470	867	286	459	1612
Physiography	498	1232	734	2464	434	442	349	1225	1069	327	918	2314
Biology	492	1068	737	2297	462	522	461	1445	942	306	698	1946
Physics	413	960	581	1954	400	497	332	1229	1144	500	1044	2688
Chemistry	212	834	444	1490	335	652	396	1383	1386	447	1093	2926
Total	2206	5400	3613	11219	2205	2553	1994	6752	5408	1866	4212	11486

Grand total, 29457 marks

Only the most roughly approximate conclusions may be drawn from these gross totals, however. The marks must be classified more minutely; and percentages, instead of absolute figures, used in order to equalize the differences in the number of answers received from each grade, or for each science.

PERCENTAGE TABLES OF THE MARKS.

The first assembling of the individual test papers for purposes of classification is by "unit groups" into which the papers of one grade, one science, and one test topic are collected. There are 750 such groups. In each test paper there are three questions marked, the significance of which has been previously explained. The median number of answers included in each unit group is 13, with variations from zero to 37, with practically normal distribution.

The per cent of A's, B's, and C's for each of the three questions was calculated for each unit group. Then the 25 groups which comprize all of the questions in one science answered by the children of one grade were ranked, and the quartiles, median, and average determined. These figures, therefore, represent the characteristic reaction of the children in each separate grade to each separate science. This data is set out in Table XIII.

The use of the per cent instead of the actual numerical count of A's, B's, and C's in these answers equalized the variations in the number of answers in the different topics, the different sciences, and the different grades. For example, 100 A's in a group of 200 is a much larger proportion than 100 A's in a group of 300, although the numerical count is the same; a percentage alone expresses the true relation.

The use of the median in recording the central characteristic value for these per cents neutralizes another possible source of error which might affect the conclusions. Suppose certain questions have been grossly unfair, and not characteristic of the sciences they were supposed to represent. The replies would contain an abnormal per cent of correct or incorrect answers, depending on the unnatural ease or difficulty of the question. Each of these would greatly influence the average, but would simply form an extreme case where the median is used, not affecting its value more than one step at the utmost and having no greater effect on the nearest quartile.

In the table the average is included for each case, and will show, by its deviation from the median, whether such uncompensated extreme cases exist. From the upper and

lower quartiles those groups in which the cases are concentrated in the higher or lower ranks, or those cases in which the distribution is more uniform, may be discerned. The most significant figures, however, are the respective medians, which record the reactions of the children in each science.

TABLE XIII.

Percentage Table of the Marks.

Fifth Grade.

		Physiology %	*Physiography* %	*Biology* %	*Physics* %	*Chemistry* %
		Question 1. Previous Knowledge.				
A's.	3 Q	20.	38.88	23.61	20.	0
	M	5.88	0	0	0	0
	1 Q	0	0	0	0	0
	Av.	13.14	18.49	13.83	11.06	3.11
B's.	3 Q	40.68	24.03	24.03	32.05	20.48
	M	25.	11.11	0	7.17	0
	1 Q	9.58	0	0	0	0
	Av.	28.85	15.18	15.50	17.45	11.03
C's.	3 Q	87.87	100.	100.	92.58	100.
	M	60.	71.43	72.11	80.90	93.75
	1 Q	32.29	38.89	45.39	56.30	75.55
	Av.	58.01	66.33	70.67	71.49	85.86
		Question 2. Direct Assimilation.				
A's.	3 Q	69.05	63.34	53.57	36.10	27.21
	M	35.71	30.78	25.	16.78	16.67
	1 Q	19.09	0	14.83	0	0
	Av.	42.06	34.17	32.51	19.22	18.36
B's.	3 Q	40.	61.91	48.19	38.25	50.
	M	28.57	31.25	26.38	25.	37.50
	1 Q	14.28	20.83	20.	14.37	18.34
	Av.	28.27	37.88	31.55	25.97	34.39
C's.	3 Q	45.56	41.88	50.	69.05	66.67
	M	22.73	28.57	25.	51.32	44.45
	1 Q	16.53	9.40	21.82	39.23	23.61
	Av.	29.67	27.99	34.14	54.81	47.25
		Question 3. Power of Application.				
A's.	3 Q	58.57	35.41	42.22	26.97	25.
	M	36.36	14.29	24.11	11.11	0
	1 Q	12.91	0	3.33	0	0
	Av.	34.72	24.27	27.15	14.59	10.36
B's.	3 Q	38.18	25.96	40.	19.09	33.33
	M	28.57	11.11	26.78	6.48	8.33
	1 Q	16.67	0	3.33	0	0
	Av.	28.01	16.59	25.69	11.03	15.76
C's.	3 Q	51.67	87.30	73.21	100.	100.
	M	33.33	62.5	42.22	76.92	75.
	1 Q	20.56	35.89	24.11	58.33	55.83
	Av.	37.27	59.14	47.16	74.38	73.88

SIXTH X GRADE.

		Physiology %	Physiography %	Biology %	Physics %	Chemistry %
A's.		Question 1. Previous Knowledge.				
	3 Q	51.09	50.	38.18	23.07	17.14
	M	12.5	16.67	7.69	8.39	0
	1 Q	2.78	0	0	0	0
	Av.	28.75	25.12	21.83	18.34	9.25
B's.						
	3 Q	33.33	30.95	33.33	33.24	14.58
	M	21.43	17.65	21.43	13.33	0
	1 Q	12.23	0	3.57	0	0
	Av.	23.88	20.39	24.14	21.15	9.36
C's.						
	3 Q	66.67	79.09	85.17	90.20	100.
	M	50.	55.55	50.	65.87	91.67
	1 Q	26.78	25.	25.	41.43	70.83
	Av.	47.37	54.49	54.03	60.51	81.39
A's.		Question 2. Direct Assimilation.				
	3 Q	94.45	81.05	86.43	57.24	62.01
	M	75.	55.55	50.	39.23	40.
	1 Q	30.95	50.	35.68	14.08	12.5
	Av.	64.87	60.07	54.62	39.59	40.66
B's.						
	3 Q	36.60	33.33	43.07	50.	53.57
	M	20.	18.75	25.	29.67	28.07
	1 Q	3.84	3.34	8.57	20.91	13.94
	Av.	23.	20.28	26.50	35.73	34.65
C's.						
	3 Q	26.67	42.73	29.28	40.	38.46
	M	0	12.5	28.	18.46	20.
	1 Q	0	0	0	2.94	7.70
	Av.	12.13	19.65	18.88	24.68	24.69
A's.		Question 3. Power of Application.				
	3 Q	84.53	66.52	50.	42.26	34.13
	M	50.	30.77	33.33	30.	15.38
	1 Q	30.56	14.58	17.14	2.94	0
	Av.	56.06	39.34	36.54	26.17	17.27
B's.						
	3 Q	33.33	22.71	39.23	25.38	37.98
	M	25.	14.28	25.	10.26	25.
	1 Q	3.57	0	17.14	0	1.78
	Av.	21.08	15.15	27.01	13.55	22.16
C's.						
	3 Q	38.19	74.82	60.	87.5	73.21
	M	18.19	41.67	29.41	51.92	66.67
	1 Q	3.57	25.	15.00	39.23	43.75
	Av.	22.86	45.51	36.45	60.28	60.57

SIXTH R GRADE

		Physiology %	Physiography %	Biology %	Physics %	Chemistry %
A's.		Question 1. Previous Knowledge.				
	3 Q	31.37	25.66	33.80	28.28	15.
	M	15.38	17.78	12.5	4.76	0
	1 Q	0	0	5.15	0	0
	Av.	18.77	20.05	22.17	15.63	8.39
B's.						
	3 Q	41.27	33.30	33.81	36.47	23.61
	M	23.81	21.12	23.07	13.33	8.33
	1 Q	13.80	10.53	8.42	7.69	0
	Av.	28.29	23.	23.57	18.46	12.73
C's.						
	3 Q	73.51	75.96	73.46	85.84	100.
	M	61.54	57.77	60.	64.28	88.89
	1 Q	26.49	31.58	26.68	51.19	66.44
	Av.	52.94	56.95	54.26	65.91	78.88
A's.		Question 2. Direct Assimilation.				
	3 Q	75.30	71.85	64.97	55.49	47.22
	M	55.56	60.	46.15	40.91	25.
	1 Q	28.57	30.38	30.30	16.67	20.53
	Av.	54.22	52.	48.27	39.59	34.39
B's.						
	3 Q	42.02	39.23	45.23	38.13	57.73
	M	23.08	22.87	37.5	26.32	40.
	1 Q	17.16	13.48	20.83	14.83	23.01
	Av.	27.62	25.99	32.61	26.28	37.03
C's.						
	3 Q	35.50	28.83	30.30	50.	42.78
	M	8.76	12.91	18.75	29.41	23.53
	1 Q	1.97	9.55	4.56	15.58	9.16
	Av.	18.16	22.01	19.12	34.13	28.58
A's.		Question 3. Power of Application.				
	3 Q	61.71	43.91	46.41	39.28	31.66
	M	40.	30.49	33.33	25.	11.11
	1 Q	23.27	12.41	18.07	5.84	2.5
	Av.	42.32	31.65	32.35	23.87	19.18
B's.						
	3 Q	33.56	27.96	37.98	27.63	30.95
	M	26.67	19.90	26.92	14.29	16.67
	1 Q	18.75	5.57	13.39	7.41	8.71
	Av.	26.84	17.53	26.92	16.87	20.26
C's.						
	3 Q	46.03	73.57	57.36	82.44	82.84
	M	23.08	49.87	33.33	58.33	64.92
	1 Q	12.13	29.70	21.64	37.85	38.19
	Av.	30.84	50.82	40.73	59.26	60.56

SEVENTH X GRADE.

		Physiology %	Physiography %	Biology %	Physics %	Chemistry %
A's.		Question 1. Previous Knowledge.				
	3 Q	60.38	61.25	50.	45.	19.64
	M	33.33	20.	25.	20.	0
	1 Q	11.11	0	6.	0	0
	Av.	36.21	29.46	29.75	26.67	10.80
B's.						
	3 Q	49.71	31.66	50.	28.57	45.83
	M	28.57	20.	30.77	12.5	15.38
	1 Q	0	4.16	0	0	0
	Av.	27.62	23.69	32.96	23.11	23.92
C's.						
	3 Q	57.78	68.33	52.78	77.35	96.67
	M	33.33	36.36	33.33	55.56	83.33
	1 Q	10.8	21.67	18.33	12.14	38.88
	Av.	36.11	46.85	37.29	50.22	65.28
A's.		Question 2. Direct Assimilation.				
	3 Q	95.4	85.72	88.75	77.5	66.67
	M	81.82	77.78	66.67	50.	50.
	1 Q	53.57	51.92	44.15	33.33	34.84
	Av.	70.94	67.75	62.98	53.65	51.48
B's.						
	3 Q	30.95	35.89	41.93	36.67	50.
	M	14.28	15.38	27.27	23.87	26.62
	1 Q	0	8.71	5.	16.67	15.48
	Av.	18.31	15.38	26.62	27.29	32.88
C's.						
	3 Q	12.96	17.42	13.76	32.05	24.74
	M	0	11.11	0	16.67	12.5
	1 Q	0	0	0	0	0
	Av.	10.77	12.24	10.40	19.06	15.64
A's.		Question 3. Power of Application.				
	3 Q	87.86	72.11	51.66	53.57	39.58
	M	72.72	50.	33.33	28.57	28.57
	1 Q	50.	17.42	18.33	5.55	13.39
	Av.	64.48	47.78	37.49	31.41	30.1
B's.						
	3 Q	30.3	24.74	48.07	39.18	38.59
	M	15.39	10.	18.18	16.67	16.67
	1 Q	0	0	9.57	0	0
	Av.	19.36	14.35	27.02	20.53	20.84
C's.						
	3 Q	16.78	56.35	69.05	73.86	75.
	M	0	33.33	20.	47.62	50.
	1 Q	0	21.11	4.55	25.	21.82
	Av.	16.16	37.87	35.49	48.06	49.06

SEVENTH R GRADE.

		Physiology %	*Physiography* %	*Biology* %	*Physics* %	*Chemistry* %
A's.		Question 1. Previous Knowledge.				
	3 Q	48.42	48.68	35.41	43.91	18.33
	M	31.17	29.96	13.64	21.43	9.52
	1 Q	13.64	5.44	7.14	0	0
	Av.	31.17	29.96	24.24	25.02	12.08
B's.						
	3 Q	42.22	26.50	37.71	37.98	31.64
	M	29.41	20.	23.54	21.43	10.
	1 Q	19.47	12.40	14.89	6.45	4.65
	Av.	31.	21.	26.67	24.06	18.6
C's.						
	3 Q	53.93	75.5	72.24	77.38	92.51
	M	36.36	50.	50.	47.06	73.68
	1 Q	16.23	21.5	33.27	28.85	49.81
	Av.	37.83	49.04	49.1	50.92	69.32
A's.		Question 2. Direct Assimilation.				
	3 Q	82.24	87.59	79.28	75.49	57.78
	M	73.34	73.34	60.	58.14	44.45
	1 Q	50.	51.47	41.88	35.12	27.67
	Av.	67.08	68.9	59.93	56.2	45.35
B's.						
	3 Q	27.28	28.04	45.31	30.21	50.
	M	18.18	11.77	23.54	23.81	37.5
	1 Q	9.52	5.28	13.58	14.64	18.6
	Av.	20.02	17.75	27.07	24.06	35.32
C's.						
	3 Q	23.02	17.42	18.	32.05	26.05
	M	9.52	11.77	13.33	14.29	18.18
	1 Q	0	3.97	5.88	6.25	7.1
	Av.	12.9	13.35	13.	19.74	19.33
A's.		Question 3. Power of Application.				
	3 Q	81.8	66.83	55.08	50.	43.74
	M	63.64	29.41	42.86	35.	22.22
	1 Q	48.33	16.23	30.95	10.26	10.1
	Av.	60.74	38.35	41.44	33.44	25.18
B's.						
	3 Q	27.52	28.22	34.31	23.52	32.66
	M	15.	16.	20.	14.29	16.67
	1 Q	6.66	5.44	10.43	6.07	9.55
	Av.	19.48	16.87	22.37	15.66	19.94
C's.						
	3 Q	28.59	63.86	48.81	82.29	75.49
	M	13.63	45.45	33.33	45.	52.94
	1 Q	6.66	27.21	23.02	26.68	28.66
	Av.	19.78	44.78	36.19	50.9	54.88

EIGHTH GRADE.

		Physiology %	*Physiography* %	*Biology* %	*Physics* %	*Chemistry* %
		Question 1. Previous Knowledge.				
A's.	3 Q	66.67	53.75	63.33	43.21	22.64
	M	40.91	18.18	26.67	25.	6.67
	1 Q	25.39	0	11.11	15.34	0
	Av.	45.69	29.90	37.76	30.21	15.75
B's.	3 Q	48.44	36.93	38.75	37.64	41.25
	M	27.28	22.22	33.33	25.	23.07
	1 Q	10.55	8.01	10.55	10.55	6.9
	Av.	30.36	23.76	27.34	26.84	25.
C's.	3 Q	43.33	71.19	55.05	66.67	85.63
	M	18.18	45.46	33.33	35.71	60.
	1 Q	0	23.61	9.41	17.5	40.
	Av.	23.95	46.34	34.9	43.02	59.25
		Question 2. Direct Assimilation.				
A's.	3 Q	100.	97.92	93.33	86.39	73.61
	M	80.	78.57	77.77	62.5	62.5
	1 Q	73.89	61.82	59.92	50.	51.66
	Av.	80.97	77.23	75.64	64.03	60.44
B's.	3 Q	19.37	32.05	32.76	39.28	35.43
	M	10.	15.38	15.38	22.22	25.
	1 Q	0	0	6.11	10.	18.18
	Av.	12.1	16.33	17.84	23.34	25.
C's.	3 Q	15.55	9	10.76	23.61	15.85
	M	0	0	5.56	6.66	7.7
	1 Q	0	0	0	0	0
	Av.	6.93	6.44	6.52	12.63	14.43
		Question 3. Power of Application.				
A's.	3 Q	90.69	75.6	69.	63.75	50.
	M	66.67	52.18	60.	42.86	35.
	1 Q	60.	27.18	35.08	20.71	12.91
	Av.	71.73	50.8	51.8	41.56	33.86
B's.	3 Q	25.83	28.87	26.59	23.61	27.92
	M	12.5	15.39	14.28	16.67	10.52
	1 Q	5.41	4.95	7.88	7.73	3.12
	Av.	16.85	17.11	17:5	17.73	18.34
C's.	3 Q	18.74	48.08	43.05	54.25	72.38
	M	10.	30.77	28.57	35.29	45.46
	1 Q	0	17.42	11.27	23.21	23.21
	Av.	11.42	32.09	30.7	40.7	47.8

Examination of the medians reveals that in most cases the grades may be ranked according to the general ability of children to assimilate the facts of science in the order:

5, 6r, 6x, 7r, 7x, 8.

That this ranking is thoroughly characteristic is shown when the averages of the medians of all sciences in a particular grade are recorded and ranked. The increments, or differences from grade to grade, will show any excep-

tions to the general tendency for the average per cents to progress from grade to grade in the typical order. These averages, and increments, are recorded in Table XIV.

With one exception of very small value (6r-6x, Question 1), the increments in the A's from the fifth to eighth grades are positive for all three questions. The increments in the C's are negative for all questions. Those in the B's vary from positive to negative by small amounts. The rank order of the grades as given above seems firmly established.

TABLE XIV.

AVERAGES FOR THE MEDIAN PER CENTS IN EACH GRADE.

ALL SCIENCES INCLUDED.

A's.

Grades	5	6r	6x	7r	7x	8
Question 1	1.17	10.08	9.05	17.25	19.67	23.48
Question 2	24.95	45.52	51.96	61.85	65.25	72.27
Question 3	17.17	27.99	31.90	38.63	42.64	51.34

A's. Increments between—

Grades	5 and 6r	6r and 6x	6x and 7r	7r and 7x	7x and 8
Question 1	+8.91	—1.03	+8.20	+2.42	+3.81
Question 2	+20.57	+6.44	+9.89	+3.40	+7.02
Question 3	+10.82	+3.91	+6.73	+4.01	+8.70
Sum of increments	+40.30	+9.32	+24.82	+9.83	+19.53
Average of increments	13.43	3.79	8.27	3.28	6.51

B's. Averages.

Grades	5	6r	6x	7r	7x	8
Question 1	8.65	17.93	14.77	20.88	21.44	26.18
Question 2	29.74	25.95	24.3	22.96	22.81	17.60
Question 3	16.25	20.89	19.91	16.39	15.38	13.87

B's. Increments between—

Grades	5 and 6r	6r and 6x	6x and 7r	7r and 7x	7x and 8
Question 1	+9.28	—3.16	+6.11	+.56	+4.74
Question 2	—3.79	—1.65	—1.34	—.15	—5.21
Question 3	+4.64	—.92	—3.52	—1.01	—1.51
Sum of increments	+10.13	—5.73	+1.25	—.60	—1.98
Average of increments	5.90	1.91	3.66	.57	3.82

C's. Averages.

Grades	5	6r	6x	7r	7x	8
Question 1	75.62	66.49	62.62	51.7	48.38	38.54
Question 2	34.41	18.67	15.79	13.42	8.06	3.98
Question 3	57.95	45.90	41.57	38.07	30.19	30.02

C's. Increments between—

Grades	5 and 6r	6r and 6x	6x and 7r	7r and 7x	7x and 8
Question 1	—9.13	—3.87	—10.92	—3.32	—9.84
Question 2	—15.74	—2.88	—2.37	—5.37	—4.08
Question 3	—12.05	—4.33	—3.50	—7.88	—.17
Sum of increments	—36.92	—11.08	—16.79	—16.57	—14.09
Average of increments	12.31	3.69	5.60	5.51	4.70

Examination of the medians reveals that in most cases the sciences may be ranked according to the general ability of children to assimilate their characteristic facts in the order—

Physiology, Physiography, Biology, Physics, Chemistry.

That this ranking is typical is shown when the average of

the medians of all grades in each particular science are recorded and ranked. The increments, or differences from science to science, will show any exceptions to the general tendency for the average per cents to progress from science to science in the typical order. These averages and increments are recorded in Table XV.

With one small exception (Physiography-Biology in Question 3), the increments of the A's in the sciences ranked from Physiology to Chemistry are negative. With three exceptions, only one of consequence (Physiography-Biology, Question 3), the increments in the C's are positive. The B's vary in sign. In comparing Physiography and Biology, it is seen that the latter possesses a large excess of B's, which explains the exceptions noted above. In all other respects the rank order of the sciences as given above seems to be thoroughly characteristic.

TABLE XV.

AVERAGES FOR THE MEDIAN PER CENTS IN EACH SCIENCE

ALL GRADES INCLUDED.

A's. Averages.

Science	*Physiology*	*Physiography*	*Biology*	*Physics*	*Chemistry*
Question 1	22.59	14.67	14.25	13.26	2.69
Question 2	66.90	62.67	54.26	44.89	39.77
Question 3	54.90	34.52	37.83	28.76	18.71

A's. Increments between—

	Physiology and Physiography	*and Biology*	*and Physics*	*and Chemistry*
Question 1	—7.92	—.42	—.99	—10.57
Question 2	—4.23	—8.41	—9.37	—5.02
Question 3	—20.38	+ 3.31	—9.07	—10.05
Sum of increments	—32.53	—5.52	—19.43	—25.64
Average of increments	10.84	3.05	6.48	8.55

B's. Averages.

Science	*Physiology*	*Physiography*	*Biology*	*Physics*	*Chemistry*
Question 1	25.92	18.70	22.02	15.46	9.46
Question 2	19.02	19.23	25.85	25.14	33.58
Question 3	20.52	14.45	21.86	13.11	15.64

B's. Increments between—

	Physiology and Physiography	*and Biology*	*and Physics*	*and Chemistry*
Question 1	—7.22	+ 3.32	—6.56	—6.00
Question 2	+ .21	+ 6.62	—.71	+ 8.44
Question 3	—5.93	+ 7.41	—8.75	+ 2.53
Sum of increments	—12.94	+ 17.35	—16.02	+ 4.97
Average of increments	4.45	5.78	5.34	3.66

C's. Averages.

Science	*Physiology*	*Physiography*	*Biology*	*Physics*	*Chemistry*
Question 1	43.24	52.76	49.80	58.23	81.89
Question 2	6.84	12.81	15.11	22.64	21.06
Question 3	16.37	43.93	31.14	52.51	59.17

C's. Increments between—

	Physiology and Physiography	*and Biology*	*and Physics*	*and Chemistry*
Question 1	+ 9.52	—2.96	+ 8.43	+ 23.66
Question 2	+ 5.97	+ 2.30	+ 7.53	—1.58
Question 3	+ 27.56	—12.79	+ 21.37	+ 6.66
Sum of increments	+ 43.05	—13.45	+ 37.33	+ 28.74
Average of increments	14.35	5.28	12.44	10.11

Interpretation of the Reactions. General Characteristics in the Grades.

Question 1. The Previous Knowledge of Children.

Children of the fifth grade have very little information concerning even the simplest phenomena of science. The median per cent of correct answers received to questions which were designed to probe their minds for knowledge already possessed was zero for all sciences except Physiology-Hygiene, and less than 6% in that instance. There is an exceedingly small apperceptive foundation upon which to build General Science instruction in the fifth grade.

In the sixth grades, information concerning the body, and health (Physiology), also land forms and the weather (Physiography), have become appreciably more familiar; but the phenomena of Physics and Chemistry still are not matters of common knowledge. In the seventh grade, all of the sciences except Chemistry show reasonable medians, which, in the eighth grade, are slightly increased, with the exception of Physiography, which remains practically the same. Physiology-Hygiene is decidedly in the lead in these two grades, probably due, in many cases, to some definite instruction which has begun in that subject.

It is difficult to arbitrarily determine the amount of previous knowledge which could furnish a sufficient basis for beginning instruction in a particular science. Certainly it would seem unwise from this data to place ordinary topics of the five sciences before children of the fifth grade and expect them to really understand. The possibility of learning rules concerning any science by rote is, of course, admitted; but this is not the type of instruction under discussion. There are also the elementary types of "Nature Primers" and "Natural Science Readers" which have been often used in the fifth and lower grades; but this extremely simple treatment would hardly entitle the topics to be classed with the characteristic subject-matter of Physics, Physiography, etc., in General Science texts.

If, for illustration, 15% be taken as a reasonable median, representing the per cent of a class of students which would have previous knowledge of a science, then the standard topics of Physiology-Hygiene and Physiography might be given in the sixth grade, and Physics and Biology added in the seventh grade. It is doubtful whether the almost total ignorance of Chemistry would permit a recommendation that it be included in even the eighth grade. As a general principle, there should be a modicum of apperception upon which to build a child's knowledge in a science by instruc-

tion, and, under the circumstances, the expediency of chemical instruction is seriously to be questioned in the grades.

In all sciences the median per cents of C's progressively decrease, with two slight exceptions, from the fifth to the eighth grade. They tend to confirm the inferences drawn from the distribution of the A's, representing as they do the approximate reciprocals of the percentages of the A's.

Question 2. The power of Direct Assimilation possessed by children.

It is believed that the child's state of mind when answering Question 2 of the test topic immediately after having studied a direct statement of some scientific fact closely approximates his state of mind when reciting to a teacher, or engaging in a written exercise, concerning topics which have been previously studied from a textbook. The advantage of recency, and of having but one topic to hold in mind, lies with this test; the disadvantage of dealing with an isolated topic, not linked with any project or lesson plan, is also a factor, which may compensate the advantage of recency. It is the belief of the writer that the conditions of the test favor as good, or possibly better, reactions from the children in the form of correct answers as would be found in the ordinary recitation or written exercise. If this be true, a reasonably high standard of median per cents for A's in the answers of Question 2 may be set to indicate a satisfactory performance.

Can any median for Question 2 in the fifth grade be considered satisfactory? Would not a written test in any subject which 36% or less of a class of normal children could pass be considered unreasonable? And if the pupils had just given diligent study to the points covered by the test, would not the subject-matter which had been assigned to them which could be assimilated by only 36% or less of the class be considered above their mental grasp? In the fifth grade, Physiology ranks highest with most A's and fewest C's, but the median is very low in comparison with other grades. Physics and Chemistry rank lowest in A's, and the per cent of C's is correspondingly high, showing that the inability of children to assimilate these topics is definite and positive. It does not appear that in the fifth grade the children are capable of really understanding any reasonable proportion of truly representative topics of the principal sciences. Here, again, the possibility of learning by rote or becoming interested in childish primers is admitted; but this study refers to the real subject-matter and principles of science, expressed with simplicity, but based upon

the topics which a majority of the authors of General Science texts considered indispensable.

As a basis of discussion, let approximately 60% be designated as a satisfactory median. If it is reasonable to expect that 60% of a class should pass the average test, then values less than this per cent would indicate subject-matter too difficult for their comprehension. It would then appear that the first definite science instruction would be properly given in the sixth grade, and would include the topics of Physiology-Hygiene and Physiography. The fields of Biology, and possibly Physics, could be drawn upon for characteristic information in the seventh grade. Physics is appropriate for the eighth grade, and Chemistry is barely over the line. The rank of Physics and Chemistry in this grade compared with the other sciences shows that they present far greater difficulties to children in the assimilation of their subject-matter. Any outline of simplified topics which pupils in grades below the eighth could pass over with high marks would probably have to eliminate some of the most definite and characteristic principles of these two sciences.

Again, the C's consistently decrease from the fifth to the eighth grades, coming to a vanishing point in Physiology, Physiography, and Biology. The low per cent of C's in Physics and Chemistry encourage consideration for these sciences in the eighth grade, since the failures, in large proportion, are only partial. The excess of B's in the eighth grade for each of these two sciences over the B's for the other sciences is very marked.

Question 3. The power of Application possessed by children.

The surest test for a statement learned by rote is to attempt to use it as a basis for further questioning. There is no prominent fact of science that is not coördinated with many other topics, usually in simple and obvious relationships. Question 3 of the test topic involved a step beyond the mere understanding of the statement presented to the child; it tested the genuineness of the child's assimilation. In a good recitation a teacher follows the expressions of one pupil with a logically related question addressed to the same or another pupil, and each individual student, in his response, is supposed to reason from the statements of his predecessor.

While an increase in the power of application from the fifth to the eighth grade is shown, it is not characterized by the regularity found in the answers from questions based on previous knowledge and direct assimilation. In the fifth

grade the median per cents of A's are low for Question 3, except in Physiology, this power of application being probably due to the greater amount of previous knowledge possessed in that subject. In the sixth and seventh grades a fair proportion of the children appear to be able to apply their knowledge in all sciences except Chemistry. The per cents for Physics and Biology remain practically stationary for these grades, while Physiography shows a serious inconsistency between the median per cents in the 7r and 7x grades which has been verified, but not explained. The per cent of A's for Chemistry does not reach acceptable proportions. Physiology-Hygiene alone has increased steadily, and has the highest rank at all times.

In the eighth grade, Physiology still leads in A's, although the pupils who are to be graduated in the 7x grade seem to have reasoned slightly better than those who will graduate in the eighth. Physiography has about the same status as in the seventh grade, while Biology has suddenly attained a satisfactory rank. Physics has also shown a marked improvement, though still ranking low. Chemistry still presents insuperable obstacles to the use of logical reason. The C's show the same general decrease in the higher grades, while the B's possess a uniformity which largely neutralizes their possible influence on the conclusions. The general results obtained from the question designed to show powers of application are nowhere inconsistent with the interpretations from the data on previous knowledge and direct assimilation.

Comparison of the R and X Grades.

Since the "last three grammar grades" comprise two distinct groups—the 5th, 6th, 7th, and the 6th, 7th, 8th—in different schools, it is of interest to determine whether there is any appreciable difference in the reaction of children who have the same number of years to go before graduation. Using the tabulation of the median per cents of A's from Table XIV., it is shown that better reactions are given by the children of the 6x and 7x grades in comparison to those of the similarly numbered 6r and 7r grades. They do not rank as high as the corresponding grades measured backward from graduation, the 7r and the 8th grades, the difference being greater in this comparison than in the first—that is, there is less difference between the grades numbered 6 (6r and 6x), also the grades numbered 7 (7r and 7x), than between the grades taken the year before graduation (6x and 7r) and the grades taken the year of graduation (7x and 8). Those who are graduating in the

seventh grade are better able to understand the principles of science than the seventh-grade pupils of the other group, but are not as capable as those who are graduating in the eighth grade.

The conclusions based upon the A's are confirmed by the percentages of the C's. The differences between the two sixth grades, also the two seventh grades, appear even less when the B's are considered; for while the 6x grade has more A's, the 6r grade has more B's; the 7x grade has more A's, the 7r grade more B's. While it was appropriate to tabulate the results for the six grades separately, yet if a combination had been made, the grouping by numerical grades—i. e., 5, 6r-6x, 7r-7x, 8—would have more correctly represented the similar abilities of children.

General Comparison of the Percentages in the Sciences.

Examination of the average percentages for each science, all grades included, reveals two outstanding points. First, the decided ability of children above the fifth grade to master the characteristic topic of Physiology-Hygiene—a tribute, no doubt, to the efforts which have been made for many years to spread the gospel of health and sanitation to every one who is able to read. This fact, coupled with the definite personal relation which health has to the individual and the references concerning disease and its cause which are constantly made in every home, may account for the large amount of previous knowledge, the high assimilability, and the satisfactory response to further questioning shown in the grades studied. Second, the apparent inability of the same group of children, even in the eighth grade, to assimilate the typical facts of Chemistry, is equally striking. The previous knowledge which children in the grades studied may have of Chemistry is only one-eleventh that of their knowledge of Physiology. Their power of assimilation is only one-half, and their power of application is only one-third in the same connection.

In these same three particulars the sciences of Physiography, Biology, and Physics rank in the order mentioned. In previous knowledge their differences are very moderate, the typical per cent being approximately two-thirds that of Physiology. In direct assimilation, Physiography is almost as suitable as Physiology, Biology ranks considerably lower, while Physics is but little more appropriate than Chemistry. In the power of application, Physiography and Biology are almost identical in rank, while Physics again presents serious difficulties.

SUMMARY OF INTERPRETATIONS.

1. A representative list of the principles of science cannot be effectively presented to children of the fifth grade and below. They lack a sufficient apperceptive foundation of previous experience; they are not able to directly assimilate any reasonable number of characteristic ideas of science and express them again; their minds have not sufficiently developed so that powers of logical reasoning might be expected.

2. In the sixth grade, Physiology and Physiography alone seem to be suitable for science instruction. There is a reasonable amount of previous knowledge possessed by children in this grade, and the characteristic and fundamental topics of these sciences seem to be satisfactorily assimilated and logically applied according to the standards suggested.

3. In the seventh grade, Biology, and possibly a most elementary treatment of Physics, becomes appropriate according to similar standards.

4. In the eighth grade, Physics is acceptable for instruction according to similar standards.

5. That Chemistry is of doubtful value for instruction in any of the grammar grades, since its percentages in previous knowledge, direct assimilation, and power of application, all fall below the suggested standards, which are easily attained by children of some grade or grades in the other sciences.

CHAPTER XI.

AN ANALYSIS OF THE COMPLETE REACTION OF CHILDREN TO SCIENCE.

A STUDY of these data is not complete when the mere results are tabulated. The psychological aspect of the problem—the "reaction" of children of the last three grammar grades toward the presentation of the characteristic truths of science—involves not only *how well* they learn, but *how* they learn.

Three successive steps have been considered as factors in the true assimilation of the principles of science.

1. *Previous knowledge,* upon which to build the new conceptions. This necessity is fundamental to all learning, formal or informal, at all ages, and with every type of mind.

2. *Ability to assimilate* plain statements, which involves association of the ideas contained therein with previous knowledge. The power to reëxpress the statement is also an integral part of this ability.

3. *The power to apply* the information—to reason from the combined knowledge of the first two steps. This does not necessarily involve the development of further principles; it may simply be a recognition of the same principle as applying to the new phenomenon or illustration.

The data of the preceding pages show each of these factors separately for each science and each grade. The mark of A, B, or C which a child received on his response to the test of previous knowledge had its proportional influence on the final tabulations for that particular phase; each A, B, or C received in the other two factors functioned in a similar manner. But by separately recording the three marks received for each child, his reaction has been split into three sections.

With the total reaction of the child as a unit, three distinct marks in the possible rankings from best to worst are immediately obvious. A child who received three A's on his test paper could not possibly have done better; a child who received three C's could not possibly have done worse. Three B's would have been an exactly medium response. But there are twenty-seven combinations of the marks of A, B, and C in groups of three; and by the laws of chance, under no guiding influence, the marks of the 9,819 children

should have been equally divided among all twenty-seven combinations, and all shades of excellence should have been equally represented.

But there were guiding influences, and strong ones, on the reactions of these children! An overwhelming number of these three-mark sets come under certain combinations. To find out what these influences are, and to interpret their cause and possible significance, is the purpose of this further study.

Rank of the Combinations.

The number of test papers marked under each of the 27 combinations is recorded in Table XVI. The combinations are ranked for each science in each grade; and to emphasize the upper measures, all combinations above the median are written in capital letters, those below the median in small letters. Medians and quartiles are indicated.

TABLE XVI.

Distribution of the Answers in the Twenty-Seven Combinations.

Fifth Grade.

Physiology		*Physiography*		*Biology*		*Physics*		*Chemistry*	
CCC	48	CCC	45	CCC	47	3 Q CCC	83	3 Q CCC	83
3 Q CBB	29	3 Q CBC	31	3 Q CBC	26	CBC	40	M CBC	38
BAA	26	CAC	29	CBB	19	M CAC	19	cac	21
CAA	24	M AAA	17	CAA	17	bcc	16	cbb	19
M AAA	23	caa	13	M AAA	14	cbb	12	1 Q caa	12
ccb	20	aac	11	cac	13	caa	11	cab	10
cba	15	cbb	10	cab	11	aaa	6	bbc	8
cac	13	bac	8	ccb	11	1 Q aac	6	ccb	8
cbc	13	cba	8	bba	8	bcb	6	cba	5
1 Q bab	12	1 Q bbb	6	1 Q bcc	8	cca	6	bac	4
bbb	10	bbc	6	baa	7	baa	5	bcc	4
cab	10	abc	5	aab	5	bac	5	aac	2
bac	9	baa	5	aac	5	bbc	5	abc	2
aab	6	cca	5	abb	5	ccb	5	bba	2
bcc	6	aab	4	bcb	5	aba	4	bbb	2
aac	5	aba	4	cba	5	bba	4	bca	2
aba	5	bab	4	acc	4	cab	4	cca	2
bba	5	bcc	4	bbc	4	aca	3	aaa	1
abb	3	ccb	4	abc	3	acc	3	aab	1
bbc	2	bcb	3	bab	3	bab	3	aba	1
bca	2	abb	2	bac	3	bca	3	acc	1
cca	2	acc	2	acb	2	aab	2	baa	1
abc	1	cab	2	cca	2	abc	2	bcb	1
acc	1	acb	1	aba	1	cba	2	abb	0
bcb	1	bba	1	bbb	1	abb	1	aca	0
aca	0	bca	1	bca	1	bbb	1	acb	0
acb	0	aca	0	aca	0	acb	0	bab	0
Total,	291	Total,	231	Total,	230	Total,	257	Total,	230

SIXTH R GRADE.

Physiology		*Physiography*		*Biology*		*Physics*		*Chemistry*	
CCC	51	CCC	58	CBC	43	CCC	95	CCC	80
CAA	50	3 Q CBC	54	CAC	37	3 Q CBC	46	3 Q CBC	68
3 Q AAA	48	CAC	46	3 Q CCC	37	CAC	44	M CAC	50
BAA	45	AAA	41	AAA	32	M CAA	29	caa	28
M CAB	27	M CAA	36	BAA	21	aaa	23	cbb	23
cbb	27	baa	29	CAB	21	cab	21	bbc	19
bab	23	cab	24	M CBA	20	bbc	16	cab	16
cac	23	bac	21	caa	19	cbb	16	1 Q cba	14
cbc	23	1 Q aac	18	aab	18	aac	15	ccb	13
1 Q cba	18	bbb	12	cbb	16	1 Q baa	13	baa	12
bba	14	bba	11	aac	15	ccb	12	abc	10
bbc	14	ccb	11	bab	15	cba	11	bac	9
bbb	13	bab	10	1 Q bac	15	bac	10	bcc	7
aab	10	bcc	10	bbb	13	bbb	10	aac	6
bac	10	cba	9	ccb	11	abc	8	cca	6
ccb	10	aab	7	bba	10	acc	7	aaa	4
abb	6	bbc	6	bbc	8	aab	6	aba	4
bcb	6	cbb	6	bcc	7	bab	6	acc	3
aba	5	aba	4	aba	6	bcc	6	bab	3
cca	5	abc	4	abb	6	cca	6	bba	3
aac	4	aca	4	cca	6	aba	5	abb	2
abc	3	abb	3	bcb	5	bca	5	bbb	2
acc	2	acc	3	abc	4	bba	4	aab	1
aca	1	cca	3	aca	4	aca	3	bcb	1
bca	1	bcb	2	acb	2	bcb	3	aca	0
acb	0	acb	1	acc	2	acb	1	acb	0
bcc	0	bca	0	bca	2	abb	0	bca	0
Total,	439	Total,	433	Total,	395	Total,	421	Total,	384

SIXTH X GRADE.

Physiology		*Physiography*		*Biology*		*Physics*		*Chemistry*	
AAA	45	AAA	36	CBC	26	CCC	47	CBC	52
3 Q CAA	30	3 Q CCC	33	CCC	24	3 Q CBC	30	3 Q CCC	45
BAA	27	CBC	29	3 Q CAA	18	CAC	28	CAB	28
M CCC	19	M CAA	26	AAA	17	M CAA	17	M CAC	28
cbb	13	cac	25	CAC	16	aaa	15	caa	21
cbc	13	bac	14	M CBA	15	cbb	14	cbb	11
bab	10	aac	10	aab	12	aac	10	1 Q bbc	10
cac	9	1 Q baa	10	cab	12	baa	7	cba	10
1 Q cab	8	cab	7	cbb	12	bba	7	ccb	9
cba	8	ccb	7	baa	11	1 Q cab	7	abc	6
aab	7	aab	6	1 Q bab	10	bbc	6	aab	4
bba	6	bab	5	bbb	7	cba	6	acc	4
bbb	6	bba	4	cca	7	abc	5	bac	4
ccb	6	bbc	4	bac	6	bab	5	bcc	4
aba	4	bca	4	ccb	6	bcc	5	cca	4
bac	3	cba	4	aac	5	ccb	5	baa	3
bbc	3	cbb	4	bbc	5	abb	4	bab	3
bcc	3	abc	3	bcc	5	bac	4	bcb	3
cca	3	aca	3	aba	3	bbb	4	aa	2
aac	2	bbb	3	acc	3	aab	3	aac	2
abc	2	cca	3	acb	2	acc	3	aba	2
acc	1	acb	2	bba	2	bca	2	acb	2
bcb	1	bcb	2	bcb	2	cca	2	bbb	2
abb	0	abb	1	abb	1	aba	1	abb	1
aca	0	aba	0	abc	1	acb	1	aca	0
acb	0	acc	0	aca	0	bcb	1	bba	0
bca	0	bcc	0	bca	0	aca	0	bca	0
Total,	229	Total,	245	Total,	228	Total,	239	Total,	260

Seventh R Grade.

Physiology		*Physiography*		*Biology*		*Physics*		*Chemistry*	
AAA	113	AAA	67	AAA	54	CAC	59	CBC	70
3 Q CAA	70	3 Q CAC	57	BAA	44	3 Q CCC	54	3 Q CAC	58
				3 Q CAA	44				
M BAA	66	CAA	55			AAA	45	CAA	45
		CBC	41	CAC	34	CBC	38	CCC	37
ccc	28	M CCC	36	CAB	33	M CAA	33	M CAB	35
cbc	25			M CCC	31				
cba	22	baa	32			aac	30	bbc	26
aab	20	bac	31	cbc	30	baa	29	cbb	25
bab	16	aac	29	cba	18	bac	27	cba	20
1 Q cac	15	1 Q cab	18	bac	17	1 Q cab	19	bac	19
				cbb	16			1 Q ccb	16
bac	14	aab	15	bba	15	cbb	18		
bba	14	bab	13			bbc	14	aaa	14
bbb	12	cbb	13	aab	14	cca	10	baa	13
cbb	9	ccb	12	aba	14	ccb	10	bcc	12
ccb	9	bbc	10	aac	13	aba	8	cca	12
aac	8	cba	8	bab	13	abc	8	aab	10
cab	8	bba	6	bbc	10	bab	8	abc	8
aba	6	bcc	5	abc	9	bcc	7	acc	8
abb	5	abc	4	bbb	6	aab	6	aac	6
bca	5	bbb	4	bcc	6	cba	5	bab	6
bcb	4	acc	3	ccb	6	acc	4	aba	5
acb	3	aca	2	abb	4	bba	4	bba	5
bbc	3	acb	2	bcb	4	bbb	3	abb	4
bcc	3	aba	1	cca	4	abb	2	bbb	4
cca	3	abb	1	acc	2	bca	2	acb	3
abc	2	bca	1	acb	1	aca	1	bca	2
aca	2	bcb	0	bca	1	acb	1	bcb	1
acc	1	cca	0	aca	0	bcb	1	aca	0
Total,	486	Total,	466	Total,	443	Total,	446	Total,	464

Seventh X Grade.

Physiology		*Physiography*		*Biology*		*Physics*		*Chemistry*	
3 Q AAA	60	AAA	40	AAA	33	CCC	29	CBC	35
		3 Q CAA	25	3 Q BAA	26	3 Q CAA	27	3 Q CAA	31
CAA	33								
M BAA	25	CAC	25	AAB	19	CAC	19	CAB	25
		BAA	18	CAA	19	AAA	18	M CAC	21
bab	17	M AAC	15	CBC	17	AAC	15		
cba	10			M CAC	15	M CBB	15	ccc	18
cac	8	cbc	14					baa	12
1 Q aab	7	ccc	13	cab	11	baa	14	bbc	11
		cab	11	cbb	11	cbc	11	1 Q cbb	11
cab	7	bab	10	ccc	11	cab	9		
aba	6	1 Q bac	10	aac	9	bac	8	bac	9
ccc	6			1 Q bab	8	1 Q bab	7	aaa	7
bbc	5	cbb	9					abc	5
bac	4	cba	7	bbb	8	bbc	7	bab	5
cbb	4	bbb	6	bbc	8	aab	6	bcc	4
cbc	4	bbc	6	bac	7	bab	6	cba	4
bba	3	abc	5	cba	7	bba	5	ccb	4
bbb	3	bcc	5	bcc	6	cba	5	aab	3
abb	2	aab	4	abb	4	bcc	4	aac	3
aca	2	cca	4	abc	4	ccb	4	bcb	3
bcb	2	bba	2	bba	3	abc	3	aba	2
abc	1	ccb	2	ccb	2	cca	3	abb	2
acc	1	aba	1	aba	1	abb	2	cca	2
bca	1	aca	1	acb	1	acc	2	aca	1
bcc	1	acc	1	bca	1	bbb	2	acb	0
cca	1	bca	1	aca	0	acb	1	acc	0
ccb	1	abb	0	acc	0	bca	1	bba	0
aac	0	acb	0	bcb	0	bcb	1	bbb	0
acb	0	bcb	0	cca	0	aca	0	bca	0
Total,	214	Total,	235	Total,	231	Total,	224	Total,	218

EIGHTH GRADE.

Physiology		*Physiography*		*Biology*		*Physics*		*Chemistry*	
3 Q AAA	135	AAA	72	AAA	81	AAA	71	CAA	58
		3 Q CAA	47	3 Q BAA	50	3 Q CAA	39	3 Q CAC	51
M BAA	69								
		CAC	45	CAA	47	CAC	30	CBC	37
caa	30	M BAA	37	M CAC	24	BAA	29	BAA	28
aab	18					M BAC	28	M AAA	23
bab	16	cbc	25	aac	18				
1 Q bac	12	cab	23	cbc	17	cab	24	cab	22
		aab	22	cab	16	cbc	23	bac	18
cba	12	bac	21	bab	15	aac	21	ccc	18
cab	10	1 Q ccc	16	1 Q aab	14	1 Q ccc	16	aac	17
aac	8							1 Q bbc	16
bba	8	aac	15	bac	12	bbc	12		
cac	8	cba	14	ccc	12	cbb	11	cbb	12
ccc	8	bab	11	aba	10	aab	9	bab	10
bbb	7	cbb	9	cba	7	bba	8	aab	9
cbc	7	bbb	7	abb	6	bab	7	bcc	9
ccb	7	bba	6	abc	6	cba	6	cba	8
aba	4	ccb	6	bbc	6	ccb	6	abb	6
cca	3	aba	4	cbb	6	abc	5	bba	6
bbc	2	bbc	4	bba	5	aba	4	bbb	6
bcc	2	bcb	2	bbb	4	abb	4	abc	5
cbb	2	cca	2	cca	4	bca	4	acb	5
abb	1	abc	1	ccb	3	bcc	4	ccb	4
aca	1	acc	1	bcb	2	bbb	3	aba	3
acb	1	bcc	1	aca	1	cca	3	cca	3
cca	1	abb	0	acb	1	acc	2	acc	2
bcb	1	aca	0	acc	1	acb	1	bca	1
abc	0	acb	0	bcc	1	aca	0	aca	0
acc	0	bca	0	bca	0	bcb	0	bcb	0
Total,	373	Total,	391	Total,	369	Total,	370	Total,	377

There are three principal points to observe in each of these distributions.

1. The amount of concentration of marks under a few combinations—a condition indicated by the height of the upper quartile and median. The ranks of the combinations below the median are not of much significance.

2. The predominance of A's, B's, or C's in the combinations above the median, and their occurrence in connection with the questions on previous knowledge, direct assimilation, or power of application.

3. The rank of the perfect mark (AAA) and of complete failure (CCC).

Rank of the 27 combinations in the Fifth Grade.

The concentration above the median is extreme, 51.3% of the answers (658 out of 1,239) being grouped in 14.1% (19 out of 135) of the combinations. In Chemistry, two combinations, and in Physics, three combinations, contain over half the answers. The C's overwhelmingly predominate in the marks for previous knowledge and for ability to apply, while A's have a slight lead in direct assimilation. Total failure (CCC) leads in all sciences, and CBC, which is obviously only one step higher than total failure, ranks second except in Physiology. The children of this grade who are above the average intelligence are barely numerous enough to bring the perfect combination (AAA) above the median, its rank being fourth or fifth, except in Physics

and Chemistry, where its rank is 8.5 and 20.5, respectively. These subjects are in no sense suitable for fifth-grade instruction.

It appears that the extremely poor reaction of fifth-grade children to the presentation of characteristic topics of science is largely due to a lack of previous experience which might be utilized as an apperceptive basis.

Rank of the 27 combinations in the Sixth R Grade.

The concentration above the median is great, 52.1% (1,079 out of 2,072) of the answers being grouped under 17.8% of the combinations. The principal congestion is again in Chemistry and Physics. Questions on previous knowledge receive practically nothing but C's, while the A's have considerably increased their lead in direct assimilation, and are much more highly ranked, but do not predominate, in the power of application. The B's above the median are surprisingly few. Total failure (CCC) ranks highest, except in Biology, where it has given place to two better combinations. CBC has a prominent rank, either first or second, except in Physiology. Perfect response (AAA) has advanced its rank in all sciences—has almost reached the median in Physics (rank 5), but is still far away in Chemistry (rank 16.5).

The improvement over the fifth grade is decided. In Physiology the very slight excess which CCC has over CAA and AAA indicates that perfection has practically caught up with failure. In Physiography and Biology the good combinations are not far behind the poor ones. In Physics and Chemistry the failures still greatly predominate.

Children of the Sixth R Grade give satisfactory response only to Physiology-Hygiene and Physiography, except as to their previous knowledge, in which they are still deficient. The other sciences cannot be considered suitable for instruction in this grade.

Rank of the 27 combinations in the Sixth X Grade.

The concentration above the median is still great, 52.9% of the answers (636 out of 1,201) being grouped under 16.3% of the combinations. Previous knowledge still shows practically nothing but C's; but the A's are greatly in excess in direct assimilation, and are almost equal to the C's in power of application. The B's are still very scarce. In these respects the Sixth X Grade is but little different from the Sixth R Grade, but a decided advantage appears in the sciences of Physiology-Hygiene and Physiography, where perfection (AAA) has taken first place by a wide margin over failure (CCC) in the former and by a bare three answers in the latter science. In fact, Physiology-Hygiene

shows three of the best possible combinations in the three highest ranks. Perfection has not yet appeared above the median in Physics or Chemistry; only the slightest improvement in the first rank of Chemistry is to be observed.

The children of the Sixth X Grade, in the two sciences which seem to be most suitable for their study (Physiology-Hygiene and Physiography), are slightly more proficient than the children of the Sixth R Grade. Their responses are otherwise very similar.

Rank of the 27 combinations in the Seventh R Grade.

Concentration above the median is still high, 52.8% of the answers (1,219 out of 2,305) being included in 17.8% of the combinations. C's predominate in previous knowledge, but not to the extent that they do in the sixth grades. The A's are in large excess in direct assimilation, and have become equal to the C's in power of application. Practically no B's are included in the upper half of the marks. Biology joins the group of the sciences in which perfect marks (AAA) lead, and perfection (AAA) for the first time appears above the median in Physics. It is below the median only in Chemistry, ranking eleventh. In Physiology-Hygiene, complete failure (CCC) has fallen below the median for the first time in any science, and it is barely above the median in Physiography and Biology. The only three combinations above the median in Physiology are the best possible ones, the whole upper 50% of the answers being concentrated in them. Biology also contains the same best three combinations, but the upper half of the answers is not confined to them.

Rank of the 27 combinations in the Seventh X Grade.

Concentration above the median is still high, 53.9% of the answers (605 out of 1,122) being grouped in 17.8% of the combinations. Previous knowledge is very slightly better in Physics, Biology, and Physiography than it was in the Seventh R Grade, and much better than in the sixth grades. The A's predominate in all sciences in direct assimilation, and are in plurality in the power of application in all sciences except Physics and Chemistry. The perfect group (AAA) leads in all sciences except Physics and Chemistry, and is absent from above the median in Chemistry only, ranking tenth. Absolute failure (CCC) has fallen below the median in all sciences except Physics, where it again ranks first by a very narrow margin of two answers over the quite acceptable combination CAA which holds second place. Again the B's are very scarce. Other conditions vary only slightly from the Seventh R Grade.

Children of the seventh grades give satisfactory re-

sponses in all sciences except Chemistry, although Physics still presents serious difficulties. In Physiography, Biology, and Physics the good showing is made in spite of the small amount of previous knowledge, which is but little, if any, greater than that possessed by children of the sixth grades. The ability to make applications has considerably increased in the Seventh Grade.

Rank of the 27 combinations in the Eighth Grade.

There is extreme concentration above the median, the greatest found in any grade, 57.3% of the answers (1,077 out of 1,880), being included in only 14.8% of the combinations. For the first time the predominance of C's in previous knowledge is not excessive. In direct assimilation the groups are exclusively A's, except for one B in Chemistry. The C's are completely eliminated. There are twice as many A's in power of application as there are C's, with no B's.

Perfection (AAA) leads in all sciences except Chemistry, but is found above the median for the first time in that subject. Failure (CCC) has completely disappeared from the upper 50%, ranking 7.5 in Chemistry and about 10 in the other groups. BAA, an almost perfect combination, and CAA, but little less so, rank high in all sciences. In Physiology the response is almost perfect, with only the two best combinations above the median.

Children of the eighth Grade give satisfactory reactions to all sciences except Chemistry. The children have not yet acquired, however, or have been unable to classify, the amount of previous experience which would seem desirable for best results in learning a science; but the condition is far better in the eighth grade than in any previous one.

Characteristics of the sciences above the median: Physiology.

The reaction to Physiology-Hygiene is good except in the fifth grade. Perfection (AAA) is always included as one of the combinations above the median, and leads in rank from the Sixth X Grade up, the excess being very marked in the seventh and eighth grades. Failure (CCC) leads strongly in the fifth grade, has a plurality of only one answer in the Sixth R Grade, is displaced in the Sixth X Grade, and disappears from the upper 50% in the seventh and eighth grades.

Previous knowledge is fair only in the seventh and eighth grades. Direct assimilation and power of application rank perfect above the median in the seventh and eighth grades and almost perfect in the fifth and sixth grades. Phys-

iology-Hygiene is obviously the most suitable of any science for instruction in the grades.

Characteristics of the sciences above the median: Physiography.

The response in Physiography becomes good in the Sixth X Grade, only the presence of a rather large group of failures (CCC) lowering the suitability. In the Sixth R Grade the condition is not quite so good, as the failures (CCC) outrank the perfect marks (AAA). With the elimination of the failures from above the median in the seventh grades, the reaction becomes excellent.

Characteristics of the sciences above the median: Biology.

This subject in the fifth and sixth grades is less satisfactory than Physiography. The upper 50% of the answers are distributed over more different combinations, and there is a lower rank for perfection (AAA) and other more satisfactory combinations. These differences practically disappear in the seventh and eighth grades, in which perfection takes first rank, the science being obviously suitable as a source of topics for instruction in these grades.

Characteristics of the sciences above the median: Physics.

In Physics even a fair reaction cannot be claimed until the seventh grade, when perfection (AAA) becomes one of the groups above the median; but the high per cent of failures (CCC) neutralizes a large part of this good influence. The A's are plentiful in direct assimilation, however. In the eighth grade the general condition is good, the C's having been practically eliminated from the direct assimilation and power of application groups. The topics of Physics seem, therefore, to be appropriate for instruction in the eighth grade.

Characteristics of the sciences above the median: Chemistry.

The reaction to Chemistry is poor in every grade. It can hardly be called fair even in the eighth grade, where perfection (AAA) first receives a rank higher than tenth. Of the 1,026 test papers in the groups above the median, answers in previous knowledge receive only 23 A's and 28 B's. The C's are three times as numerous as the A's in the power of application. The low rank of the better combinations rather discourages the inclusion of chemical topics for instruction in any grade.

CHAPTER XII.

RANK AND SCATTER OF THE TWENTY-SEVEN COMBINATIONS.

It is instructive to know, in the case of any one of the triple mark combinations, how uniform its rank has been in the different grades in one science or in the different sciences in one grade. For example, CCC ranks first in all sciences of the fifth grade, but its relative rank is tenth in the eighth grade. AAA ranks highest in Physiology, Physiography, and Biology, but occupies the fourteenth place in Chemistry.

The marked concentration of the answers under the head of certain combinations leaves other combinations with few, if any, answers. What these combinations are, and whether they are the same in different grades and different sciences, must be determined if the cause and significance of this uneven distribution is to be studied.

If the ranks of a combination as it occurs in one science throughout all grades is averaged, a typical measure of the importance of that combination in the particular science is obtained. The average rank of a combination as it occurs in one grade, but including each science, is also a typical measure of the importance of that combination in the particular grade. The average is chosen rather than the median, because of the small number of cases—six and five, respectively, in each science and grade—and the possible range of 27 units in rank. The data of these ranks are recorded in Table XVII.

When orders of rank are assigned in this manner for each combination, either from average or median figures, it is important to know whether the position is a result of the combination occurring uniformly in that rank (as where CCC ranks first in all sciences in the fifth grade), or whether it is merely the position determined by calculation from varying ranks (as where AAA in the Sixth X Grade occupies the fifth position, with an average rank of 6.4, which has been calculated from two first ranks, one fourth, one fifth, and one twenty-first rank in the five sciences). The *dispersion* of the ranks from which the average is calculated is of value as an auxiliary to this definite average. The story of the man who was drowned while crossing a stream with an *average* depth of two feet is a simple illustration of the point.

Ordinary measures of dispersion do not appropriately apply here because of the small number of cases—five sciences, six grades. Extreme range only shows two of the

number; and if these ranks were 1 and 27, respectively, no hint of the location of the other three or four ranks would be disclosed. It is useless to calculate a quartile deviation from only five or six cases; the median deviation, the standard deviation, and the average deviation are of doubtful value for the same reason. The formula

$$\frac{100 \cdot S(d) \cdot \sqrt{S(d^2)}}{(n-1)^2} = \% \text{ of Scattering}$$

has been derived, in which d represents the differences in the successive ranks when in rank order. The steps in the derivation of this formula are as follows:

1. In two or more series where the sum of the differences of the ranks in order is the same, but the size of these individual differences is unequal and the scattering obviously not the same, if the differences are squared, added, and the square root extracted, the inequality is brought out. Example:

Series 1, 3, 5, 7, 9; differences, 2, 2, 2, 2; Sd = 8; $\sqrt{S(d^2)} = 4$.

Series 1, 2, 3, 6, 9; differences, 1, 1, 3, 3; Sd = 8; $\sqrt{S(d^2)} = 4.47$

Larger gaps in the ranks indicate a higher scatter, and the value $\sqrt{S(d^2)}$ varies in direct proportion to the size of these gaps.

2. Obviously the series 5, 6, 7, 8, 9, in which S(d) = 4, has less scatter than the series 1, 7, 14, 20, 27, in which S(d) = 26. The larger sum of the differences represents a larger scatter; therefore the quantity S(d) is a direct measure of the proportion of scattering.

These two values, $S(d) \cdot \sqrt{S(d^2)}$ represent a rectangle which, when plotted, would have as one dimension the side of the square which would contain the sum of the areas of the squared differences, and as the other dimension the total range of the ranks. This area is a measure of the actual extent of scattering.

3. This area may now be compared with the total possible area of scattering, so that the scatter of any given set of ranks may be recorded as a proportion (fraction) or as a per cent. With 27 ranks, the largest possible sum of differences is 26, or n—1, where n = the number of ranks. The area which would represent this scatter is $(n-1)^2$, and is the largest possible rectangle which could be constructed by any application of these differences. The ratio which the dispersal of any certain case bears to the largest possible scattering is the quantity $\frac{S(d) \cdot \sqrt{S(d^2)}}{(n-1)^2}$

4. To convert this ratio into per cent, multiply the numerator by 100. The formula, therefore, becomes

$$\frac{100 \cdot S(d) \cdot \sqrt{S(d^2)}}{(n-1)^2} = \text{Per Cent of Scattering of Ranks.}$$

In a given set of tables with the same number of ranks the quantity $\frac{100}{(n-1^2)}$ is a constant. With 27 ranks, $100/676 = .146$. For 25 ranks the constant is .174; for 20 ranks, .277; etc.

Graphic Proof of the Formula.

1. Given a series, such as 5, 5, 5, 5, 5, with no scattering. S(d) is zero; therefore the formula gives a zero per cent of scatter.

2. Given a series 1, 1, 27, 27, 27, where the ranks would have the greatest possible scatter from the average as calculated. Substituting, $\frac{100 \times 676 \times 26}{676} = 100\%$ Scatter.

3. Given a series of ranks 1, 7.5, 14, 20.5, 27, in which the extreme range of 26 ranks has been divided into four equal parts—i. e., four equal steps of 6.5. It is obvious that this dispersal is symmetrical to the average, which is 14, and is the exact median scatter for five ranks in 27 cases. Plotting the rectangle for the scattering to scale will indicate the actual area of scattering; another rectangle may indicate the largest possible area of scatter with 27 ranks. If these areas be superimposed, the ratio of rectangle 1 to rectangle 2 is 50%. This value is also given by calculation from the formula.

The per cent of scatter from the average has been calculated for the ranks of each combination in the separate grades, all sciences included, and for each combination in the separate sciences, all grades included. The values are recorded in Table XVII.

In connection with either the median or the average, the per cent of scatter gives a measure of the degree to which the central tendency is truly representative. The per cent may be used where the number of cases is too small to permit the use of the customary measures of deviation. Even in a large number of cases the per cent of scatter may in certain instances be more instructive than these measures, since it presents a ratio rather than an absolute quantity—that is, it measures the amount of scattering in comparison

with the largest possible scatter, rather than merely computing a value for it, which value is either an average or a median itself, and subject to all inaccuracies and disadvantages of these central tendencies. The gaps, whether located near the extremes or close to the central tendency, are measured with perfect equality, which is not true of any of the other measures of deviation, the average deviation being unduly influenced by the cases near the extreme range, and the median deviation and the quartile range ignoring them.

TABLE XVII.

RANK AND SCATTER OF THE TWENTY-SEVEN COMBINATIONS.

FIFTH GRADE.

	Science						
Combination	*Physiology*	*Physiography*	*Biology*	*Physics*	*Chemistry*	*Average Rank*	*Per Ct. of Dispersal*
CCC	1	1	1	1	1	1.	0
CBC	8.5	2	2	2	2	3.3	5.33
CBB	2	7	3	5	4	4.2	1.96
CAC	8.5	3	6	3	3	4.7	3.18
CAA	4	5	4	6	5	4.8	.42
AAA	5	4	4	8.5	20.5	8.5	30.64
CCB	6	17	7.5	12.5	7.5	10.1	11.21
BCC	14.5	17	9.5	4	10.5	11.1	14.07
BBA	17	25	9.5	16	14.5	11.9	22.03
AAC	17	6	14	8.5	14.5	12.	11.10
CBA	7	8.5	14	23	9	12.3	24.66
BAA	3	13	14	12.5	20.5	12.6	29.94
CAB	11.5	22	7.5	16	6	12.8	20.43
BAC	13	8.5	20	12.5	10.5	12.9	12.84
BBC	21	10.5	17.5	12.5	7.5	13.8	14.16
CCA	21	13	22.5	8.5	14.5	15.9	16.95
BBB	11.5	10.5	25	25.5	14.5	17.4	27.33
BCB	24	20	14	8.5	20.5	17.4	20.38
AAB	14.5	17	14	23	20.5	17.9	6.97
BAB	10	17	20	19.5	25.5	18.4	19.91
ABC	24	13	20	23	14.5	18.9	10.61
ABA	17	17	25	16	20.5	19.1	7.71
ACC	24	22	17.5	19.5	20.5	20.7	3.19
BCA	21	25	25	19.5	14.5	21.	10.22
ABB	19	22	14	25.5	25.5	21.5	10.67
ACA	26.5	27	27	19.5	25.5	25.1	6.75
ACB	26.5	25	22.5	27	25.5	25.3	1.85

Sixth R Grade.

Combination	*Science* *Physiology*	*Physiography*	*Biology*	*Physics*	*Chemistry*	*Average Rank*	*Per Ct. of Dispersal*
CCC	1	1	2.5	1	1	1.2	.33
CBC	8	2	1	2	2	3.	6.30
CAC	8	3	2.5	3	3	3.9	4.09
CAA	2	5	8	4	4	4.6	3.32
CAB	5.5	7	5.5	6	7	6.2	.25
AAA	3	4	4	5	16.5	6.5	23.12
BAA	4	6	5.5	10	10	7.1	3.82
CBB	5.5	17.5	10	7.5	5	9.1	15.11
CBA	10	15	7	12	8	10.4	4.91
BBC	11.5	17.5	17	7.5	6	11.9	11.88
BAC	15	8	12	13.5	12	12.1	4.74
CCB	15	11.5	15	11	9	12.3	3.60
AAC	21	9	12	9	14.5	13.1	11.91
BAB	8	13.5	12	18.5	19	14.2	10.74
BBB	13	10	14	13.5	21.5	14.4	13.79
BBA	11.5	11.5	16	23	19	16.2	11.44
AAB	15	16	9	18.5	23.5	16.4	19.02
BCC	26.5	13.5	18	18.5	13	17.9	18.39
CCA	19.5	23	20	18.5	14.5	19.1	6.59
ABC	22	20	23.5	15	11	19.3	12.71
ABA	19.5	20	20	21.5	16.5	19.5	2.51
ACC	23	23	26	16	19	21.4	8.62
ABB	17.5	23	20	27	21.5	21.8	7.27
BCB	17.5	25	22	24.5	23.5	22.5	5.40
ACA	24.5	20	23.5	24.5	26	24.5	3.26
BCA	24.5	27	26	21.5	26	25.	2.73
ACB	26.5	26	26	26	26	26.1	.04

Sixth X Grade.

Combination	*Science* *Physiology*	*Physiography*	*Biology*	*Physics*	*Chemistry*	*Average Rank*	*Per Ct. of Dispersal*
CCC	4	2	2	1	2	2.2	.99
CBC	5.5	3	1	2	1	2.5	1.91
CAA	2	4	3	4	5	3.6	.77
CAC	8	5	5	3	3.5	4.9	2.51
AAA	1	1	4	5	21	6.4	50.95
CAB	9.5	9.5	8	9	3.5	7.9	4.92
CBB	5.5	15	8	6	6	8.1	10.25
BAA	3	7.5	10	9	17	9.3	17.63
CBA	9.5	15	6	11.5	7.5	9.9	6.31
AAC	10.5	7.5	17	7	21	10.6	21.02
CCB	13	9.5	14.5	14	9	12.	3.02
BAB	7	12	11	14	17	12.2	8.10
AAB	11	11	8	20.5	13	12.7	13.98
BBC	17.5	15	17	11.5	7.5	13.7	8.43
BAC	17.5	6	14.5	18	13	13.8	13.81
BBB	13	19	12.5	18	21	16.7	6.91
CCA	17.5	19	12.5	22	13	16.8	7.80
BBA	13	15	22	9	26	17.	22.91
ABC	20.5	19	24.5	14	10	17.4	15.04
BCC	17.5	26	17	14	13	17.5	18.47
ACC	22.5	26	19.5	20.5	13	20.3	13.53
ABA	15	26	19.5	25	21	21.3	10.23
BCB	22.5	22.5	22	25	17	21.8	6.64
ABB	25.5	24	24.5	18	24	23.2	6.77
ACB	25.5	22.5	22	25	21	23.2	1.85
BCA	25.5	15.5	26.5	22.5	26	23.2	13.58
ACA	25.5	19	26.5	27	26	24.8	7.25

SEVENTH R GRADE.

Combination	Science: Physiology	Physiography	Biology	Physics	Chemistry	Average Rank	Per Ct. of Dispersal
CAA	2	3	2.5	5	3	3.1	.94
AAA	1	1	1	3	11	3.4	12.20
CAC	9	2	4	1	2	3.6	6.48
CBC	5	4	7	4	1	4.2	3.32
CCC	4	5	6	2	4	4.2	1.45
BAA	3	6	2.5	7	12	6.1	8.34
BAC	10.5	7	9	8	9	8.7	1.07
CAB	15.5	9	5	9	5	8.7	11.85
CBB	13.5	11.5	10	10	7	10.4	3.75
CBA	6	15	8	19	8	11.2	15.97
AAB	7	10	12.5	18	15	12.5	8.98
AAC	15.5	8	14.5	6	18.5	12.5	13.89
BAB	8	11.5	14.5	15	18.5	13.5	9.02
CCB	13.5	13	19	12.5	10	13.6	8.10
BBC	22	14	16	11	6	13.3	20.36
BBA	10.5	16	11	20.5	20.5	15.7	9.53
BCC	22	17	19	17	13.5	17.7	6.32
ABA	17	24	12.5	15	20.5	17.8	10.02
ABC	25.5	18.5	17	15	16.5	18.5	11.39
BBB	12	18.5	19	22	22.5	18.8	11.18
CCA	22	26.5	22	12.5	13.5	19.3	19.99
ACC	27	20	24	20.5	16.5	21.6	9.02
ABB	18.5	24	22	23.5	22.5	22.1	3.82
BCA	18.5	24	25.5	23.5	25	23.3	5.33
ACB	22	21.5	25.5	26	24	23.8	1.95
BCB	20	26.5	22	26	26	24.1	4.33
ACA	25.5	21.5	27	26	27	25.4	4.11

SEVENTH X GRADE.

Combination	Science: Physiology	Physiography	Biology	Physics	Chemistry	Average Rank	Per Ct. of Dispersal
CAA	2	2	3.5	2	2	2.3	.33
AAA	1	1	1	4	10	3.4	8.93
BAA	3	4	2	7	6	3.8	1.96
CCC	9.5	7	8	1	5	6.1	6.06
CAC	6	3	6	3	4	6.4	.99
CBC	13	6	5	8	1	6.6	12.04
CAB	7.5	8	8	9	3	7.1	4.12
CBB	13	11	8	5.5	7.5	9.	4.61
BAB	4	9.5	12	13.5	11.5	10.1	8.52
BBC	11	13.5	12	11.5	7.5	11.1	3.82
BAC	13	9.5	14.5	10	9	11.2	2.79
AAB	7.5	17.5	3.5	13.5	17	11.8	16.60
AAC	16.5	5	10	5.5	17	11.8	40.20
CBA	5	12	14.5	15.5	14	12.2	11.44
ABA	9.5	22	22	11.5	20	17.	16.57
BCC	22.5	15.5	16	17.5	14	17.1	6.80
ABC	22.5	15.5	17.5	19.5	11.5	17.3	9.35
BBB	15.5	13.5	12	23	25	17.8	15.68
CCB	22.5	19.5	20	17.5	14	18.7	6.00
BBA	15.5	19.5	19	15.5	25	18.9	9.19
ABB	18	26	17.5	21.5	20	20.6	4.21
CCA	22.5	17.5	25	19.5	20	20.9	4.54
BCB	18	26	25	25	17	22.2	9.51
ACA	18	22	25	27	22	22.8	7.17
ACC	22.5	22	25	21	25	23.2	1.34
BCA	22.5	22	22	25	25	23.3	1.13
ACB	26.5	26	22	25	25	24.9	2.13

EIGHTH GRADE.

Combination	Science: Physiology	Physiography	Biology	Physics	Chemistry	Average Rank	Per Ct. of Dispersal
AAA	1	1	1	1	5	1.8	2.37
CAA	3	2	3	2	1	2.2	.42
BAA	2	4	2	4	4	3.2	.59
CAC	10.5	3	4	3	2	4.5	8.36
CAB	8	6	7	6	6	6.6	.42
CBC	14	5	6	7	3	7.	12.07
BAC	6	8	10.5	5	7.5	7.6	2.54
AAC	10.5	10	5	8	9	8.5	2.73
AAB	4	7	9	12	13.5	9.1	6.92
CCC	10.5	9	10.5	9	7.5	9.3	.94
BAC	5	12	8	14	12	10.2	7.17
CBA	7	11	13	15.5	15	10.9	6.19
CBB	19	13	15.5	11	11	13.9	5.80
BBC	19	17.5	15.5	10	10	14.4	7.17
BBA	10.5	15.5	18	13	17	14.8	4.40
BBB	14	14	19.5	22.5	17	17.4	6.19
CCB	14	15.5	21	15.5	21	17.4	5.88
ABA	16	17.5	12	19.5	22.5	17.5	8.69
BCC	19	22	24.5	19.5	13.5	19.7	10.67
ABB	23	25.5	15.5	19.5	17	20.1	7.69
ABC	26.5	22	15.5	17	19.5	20.1	9.63
CCA	17	19.5	19 5	22.5	22.5	20.2	3.18
BCB	23	19.5	22	26.5	26.5	23.1	4.57
ACB	23	25.5	24.5	25	19.5	23.5	3.44
BCA	23	25.5	27	19.5	25	24.	4.80
ACC	26.5	22	24.5	24	24	24.2	1.51
ACA	23	25.5	24.5	26.5	26.5	25.2	1.07

PHYSICS.

Combination	Grades: 5	6r	6x	7r	7x	8	Average Rank	Per Cent of Dispersal
CCC	1	1	1	2	1	9	2.5	8.37
CAC	3	3	3	1	3	3	2.7	.59
CAA	6	4	4	5	2	2	3.8	1.45
CBC	2	2	2	4	8	7	4.2	3.32
AAA	8.5	5	5	3	4	1	4.4	4.74
AAC	8.5	9	7	6	5.5	8	7.4	.86
CBB	5	7.5	6	10	5.5	11	7.5	2.81
BAA	12.5	10	9	7	7	4	8.3	5.66
CAB	16	6	9	9	9	6	9.2	11.27
BBC	12.5	7.5	11.5	11	11.5	10	10.7	2.16
BAC	12.5	13.5	18	8	10	5	11.2	12.24
CCB	12.5	11	14	12.5	17.5	15.5	13.9	3.15
BCC	4	18.5	14	17	17.5	19.5	14.4	24.18
BAB	19.5	18.5	14	15	13.5	14	15.8	3.38
CBA	23	12	11.5	19	15.5	15.5	16.1	10.86
BBA	16	23	9	20.5	15.5	13	16.2	14.50
ABC	23	15	14	15	19.5	17	17.3	6.45
CCA	8.5	18.5	22.5	12.5	19.5	22.5	17.3	16.30
AAB	23	18.5	20.5	18	13.5	12	17.6	9.83
ABA	16	21.5	25	15	11.5	19.5	18.1	12.90
ACC	19.5	16	20.5	20.5	21.5	24	20.3	5.36
BBB	25.5	13.5	18	22	23	22.5	20.8	11.64
BCA	19.5	21.5	22.5	23.5	25	19.5	21.9	2.34
ABB	25.5	27	18	23.5	21.5	19.5	22.5	5.53
BCB	8.5	24.5	25	26	25	26.5	22.6	42.74
ACA	19.5	24.5	27	26	27	26.5	25.1	5.84
ACB	27	26	25	26	25	25	25.7	.42

Biology.

Combination	Grades						Average Rank	Per Cent of Dispersal
	5	*6r*	*6x*	*7r*	*7x*	*8*		
AAA	5	4	4	1	1	1	2.7	1.87
CBC	2	1	1	7	5	6	3.7	3.07
CAA	4	8	3	2.5	3.5	3	4.	3.33
CAC	6	2.5	5	4	6	4	4.6	1.07
CCC	1	2.5	2	6	8	10.5	5.	6.67
BAA	14	5.5	10	2.5	2	2	6.	11.98
CAB	7.5	5.5	8	5	8	7	6.8	.76
CBB	3	10	8	10	8	15.5	9.1	14.23
AAB	14	9	8	12.5	3.5	9	9.3	9.29
CBA	14	7	6	8	14.5	13	10.4	6.68
AAC	14	12	17	14.5	10.5	5	12.2	11.64
BAB	20	12	11	14.5	12	8	12.9	12.11
BAC	20	12	14.5	9	14.5	10.5	13.4	10.42
BBA	9.5	16	22	11	19	18	15.9	13.44
BBC	17.5	17	17	16	12	15.5	15.9	3.02
CCB	7.5	15	14.5	19	20	21	16.2	16.38
BBB	25	14	12.5	19	12	19.5	17.	14.64
BCC	9.5	18	17	19	16	24.5	17.3	19.28
ABA	25	20	19.5	12.5	22	12	18.5	12.86
ABB	14	20	24.5	22	17.5	15.5	18.9	7.45
ABC	20	23.5	24.5	17	17.5	15.5	19.7	6.24
CCA	22.5	20	12.5	22	25	19.5	20.3	14.30
BCB	14	22	22	22	25	22	21.2	14.00
ACC	17.5	26	19.5	24	25	24.5	22.7	6.38
ACB	22.5	26	22	25.5	22	24.5	23.7	1.32
BCA	25	26	26.5	25.5	22	27	25.3	2.67
ACA	27	23.5	26.5	27	25	24.5	25.6	.96

CHEMISTRY.

Combination	Grades						Average Rank	Per Cent of Dispersal
	5	*6r*	*6x*	*7r*	*7x*	*8*		
CBC	2	2	1	1	1	3	1.7	.42
CAC	3	3	3.5	2	4	2	2.9	.36
CAA	5	4	5	3	2	1	3.3	1.18
CCC	1	1	2	4	5	7.5	3.4	3.36
CAB	6	7	3.5	5	3	6	5.1	1.25
CBB	4	5	6	7	7.5	11	6.8	1.08
BBC	7.5	6	7.5	6	7.5	10	7.4	1.72
BAC	10.5	12	13	9	9	7.5	10.2	2.26
CBA	9	8.5	7.5	8	14	15	10.3	5.74
BAA	20.5	10	17	12	6	4	11.6	19.12
CCB	7.5	9	9	10	14	21	11.8	16.50
BCC	10.5	13	13	13.5	14	13.5	12.9	1.34
ABC	14.5	11	10	16.5	11.5	19.5	13.8	8.54
AAA	20.5	16.5	21	11	10	5	14.0	20.15
AAC	14.5	14.5	21	18.5	17	9	15.8	11.91
CCA	14.5	14.5	13	13	20	22.5	16.3	8.75
AAB	20.5	23.5	13	15	17	13.5	17.1	8.18
BAB	25.5	19	17	18.5	11.5	12	17.3	15.88
ACC	20.5	19	13	16.5	25	24	19.7	10.35
ABA	20.5	16.5	21	20.5	20	22.5	20.2	3.44
BBA	14.5	19	26	20	25	17	20.3	10.39
BBB	14.5	21.5	21	22.5	25	17	20.3	8.47
BCB	20.5	23	17	26	17	26.5	21.7	7.40
ABB	25.5	21.5	24	22.5	20	17	21.8	5.14
ACB	25.5	26	21	24	25	19.5	23.5	4.40
BCA	14.5	26	26	25	25	25	23.5	5.37
ACA	25.5	26	26	27	22	26.5	25.5	2.67

PHYSIOGRAPHY.

Combination	Grades 5	6r	6x	7r	7x	8	Average Rank	Per Cent of Dispersal
AAA	4	4	1	1	1	1	2.	1.33
CAC	3	3	5	2	3	3	3.2	.99
CAA	5	5	4	3	2	2	3.5	.77
CBC	2	2	3	4	6	5	3.7	1.18
CCC	1	1	2	5	7	9	4.	5.02
BAA	13	6	7.5	6	4	4	6.8	8.04
AAC	6	9	7.5	8	5	10	7.6	1.73
BAC	8.5	8	6	7	9.5	8	7.9	.70
CAB	22	7	9.5	9	8	6	10.3	29.89
CBB	7	17.5	15	11.5	11	13	12.5	9.35
BAB	17	13.5	12	11.5	9.5	12	12.6	5.42
CBA	8.5	15	15	15	12	11	12.8	3.88
AAB	17	16	11	10	17.5	7	13.1	10.66
BBB	10.5	10	19	18.5	13.5	14	14.3	7.29
CCB	17	11.5	9.5	13	19.5	15.5	14.3	6.08
BBC	10.5	17.5	15	14	13.5	17.5	14.7	4.21
BBA	25	11.5	15	16	19.5	15.5	17.1	14.88
ABC	13	20	19	18.5	15.5	22	18.	6.03
BCC	17	13.5	26	17	15.5	22	18.5	7.98
CCA	13	23	19	26.5	17.5	19.5	19.8	13.73
ABA	17	20	26	24	22	17.5	21.1	5.73
ACA	27	20	19	21.5	22	25.5	22.5	5.02
ACC	22	23	26	20	22	22	22.5	3.32
BCA	25	27	15	24	22	25.5	23.1	13.46
BCB	20	25.5	22.5	26.5	26	19.5	23.2	4.26
ABB	22	23	24	24	26	25.5	24.1	1.25
ACB	25	26	22.5	21.5	26	25.5	24.4	1.85

PHYSIOLOGY.

Combination	Grades 5	6r	6x	7r	7x	8	Average Rank	Per Cent of Dispersal
AAA	5	3	1	1	1	1	2.	1.67
CAA	4	2	2	2	2	3	2.5	.42
BAA	3	4	3	3	3	2	3.	.42
CCC	1	1	4	4	9.5	10.5	5.	8.91
BAB	10	8	7	8	4	5	7.	2.81
CBA	7	10	9.5	6	5	7	7.3	2.16
CAC	8.5	8	8	9	6	10.5	8.3	1.73
CBC	8.5	8	5.5	5	13	14	9.	7.04
CAB	11.5	5.5	9.5	15.5	7.5	8	9.5	7.32
AAB	14	15	11	7	7.5	4	9.8	9.13
CBB	2	5.5	5.5	13.5	13	19	9.8	25.02
BAC	13	15	17.5	10.5	13	6	12.5	10.31
BBA	17	11.5	13	10.5	15.5	10.5	13.	3.29
BBB	11.5	13	13	12	15.5	14	13.2	1.25
CCB	6	15	13	13.5	22.5	14	14.	25.20
ABA	17	19.5	15	17	9.5	16	15.7	9.18
BBC	21	11.5	17.5	22	11	19	17.	10.74
AAC	17	21	20.5	15	26.5	10.5	18.4	19.37
CCA	21	19.5	17.5	22	22.5	17	19.9	2.26
ABB	19	17.5	25.5	18.5	18	23	20.3	4.57
BCC	14.5	26.5	17.5	22	22.5	19	20.3	9.73
BCB	24	17.5	22.5	20	18	23	20.8	3.33
BCA	21	24	25.5	18.5	22.5	23	22.4	3.59
ABC	24	22	20.5	25.5	22.5	26.5	23.5	2.51
ACA	26.5	24.5	25.5	25.5	18	23	23.8	6.80
ACC	24	23	22.5	27	22.5	26.5	24.3	1.85
ACB	26.5	26.5	25.5	22	26.5	23	25.	1.79

THE CONCENTRATION OF ANSWERS IN CERTAIN COMBINATIONS.

The twenty-seven combinations may be ranked in each grade according to the total number of answers received, disregarding the quota of the different sciences. They may also be ranked in each science according to the total number of answers received, disregarding the quota of the

different grades. A glance at these totals as recorded in Table XVIII. shows the striking fact that certain combinations practically preëmpt the three highest and the three lowest ranks, indicating certain major tendencies in the general reactions of children toward different sciences in the different grades.

Examination of the three highest ranks for each of the grades shows that only six different combinations occupy eighteen possible positions. These combinations, and the number of times each occurs, are as follows: AAA, 4; CAA, 3; CAC, 3; CBC, 3; CCC, 3; BAA, 2. It is apparent that the power of direct assimilation of subject-matter, represented by the middle letters of these combinations, is not characteristically preceded by any appreciable amount of previous knowledge, the deficiency of which in these large groups of children is very striking. The power of application seems to appear suddenly as an acquirement of the larger groups of children in the seventh and eighth grades, this ability being lacking in the fifth and sixth grades.

The combinations most rarely met with, occupying the three lowest ranks, are only four in number for eighteen positions. Their distribution is as follows: ACA, 6; ACB, 5; BCA, 5; BCB, 2. These combinations are exclusively those in which failure in direct assimilations is accompanied by partial or complete success in the other two phases of the reaction—previous knowledge and power of application. In other words, it is inconceivable that any appreciable number of children would possess the ability to reason further along a line of scientific explanation when the direct first premise was not understood. The results here tabulated thus confirm one of the best-known pedagogical principles—that reasoning cannot proceed from the unknown. It appears equally impossible that children should fail in direct assimilation, and at the same time possess a reasonable amount of previous knowledge of the topics which they were studying. The correctness of the tendencies shown in this part of the table needs no confirmative argument.

In the sciences the fifteen positions in the three highest ranks are occupied by but six different combinations, distributed as follows: AAA, 3; CAA, 3; CAC, 3; CCC, 3; CBC, 2; CAA, 1. The general deficiency in previous knowledge, indicated by the first letter of the combinations, is evident in all sciences. Ability in the power of application, indicated by the third letter of the combinations, is characteristic of these larger groups in certain sciences—Physiology, Physiography, Biology; but the lack of this power is just as striking for Physics and Chemistry. Ability in

direct assimilation is decidedly prominent in the large groups of children in the same three sciences, and lacking in the same two as mentioned.

It appears that the reaction of children to a science shows the first evidence of success in response to direct statements and questions, and that both previous knowledge and ability to apply are products of considerable experience. Facts apparently understood from the plain statements of teacher or text are likely to remain isolated, in the mind of a child, and unaccompanied by any previous knowledge or ability to reason in a distressingly large number of cases.

The combinations rarely met with—seven different combinations, occupying fifteen positions—are again those in which satisfactory previous knowledge and successful application would be accompanied by failure in direct assimilation. We would not expect a normal child to write such a paper, and the table shows that the children did not. This principle is true of any science, as it is of any grade.

TABLE XVIII.

DISTRIBUTION OF ANSWERS, BY GRADES, IN THE TWENTY-SEVEN COMBINATIONS.

ALL SCIENCES INCLUDED.

5		6r		6x		7r		7x		8	
CCC	306	CCC	321	CCC	168	AAA	293	AAA	158	AAA	382
CBC	148	CBC	234	CBC	150	CAA	247	CAA	135	CAA	221
CAC	95	CAC	200	AAA	115	CAC	223	BAA	95	BAA	213
CBB	89	CAA	162	CAA	112	CBC	204	CAC	88	CAC	158
CAA	77	AAA	148	CAC	106	CCC	186	CBC	81	CBC	109
AAA	61	BAA	120	CAB	62	BAA	184	CCC	77	CAB	95
CCB	48	CAB	109	BAA	58	CAB	113	CAB	63	BAC	91
BAA	44	CBB	88	CBB	54	BAC	108	CBB	50	AAC	79
BCC	38	CBA	72	CBA	43	AAC	86	BAB	46	AAB	72
CAB	37	BAC	65	BAB	33	CBB	81	AAC	42	CCC	70
CBA	35	BBC	63	CCB	33	CBA	73	AAB	39	BAB	59
AAC	29	AAC	58	AAB	32	AAB	65	BAC	38	CBA	47
BAC	29	BAB	57	BAC	31	BBC	63	BBC	37	BBC	40
BBC	25	CCB	57	AAC	29	BAB	56	CBA	33	CBB	40
BAB	22	BBB	50	BBC	28	CCB	53	BCC	20	BBA	33
BBA	20	AAB	42	BBB	22	BBA	44	BBB	19	BBB	27
BBB	20	BBA	42	BBA	19	ABA	34	ABC	18	CCB	26
AAB	18	BCC	30	CCA	19	BCC	33	ABA	17	ABA	25
CCA	17	ABC	29	ABC	17	ABC	31	BBA	13	ABB	17
BCB	16	CCA	26	BCC	17	BBB	29	CCB	13	ABC	17
ABA	15	ABA	24	ACC	11	CCA	29	ABB	10	BCC	17
ABC	13	ABB	17	ABA	10	ACC	18	CCA	10	CCA	15
ABB	11	ACC	17	BCB	9	ABB	16	BCB	6	ACB	8
ACC	11	BCB	17	ABB	7	BCA	11	ACA	4	ACC	6
BCA	9	ACA	12	ACB	7	ACB	10	ACC	4	BCA	6
ACA	3	BCA	8	BCA	6	BCB	10	BCA	4	BCB	5
ACB	3	ACB	4	ACA	3	ACA	5	ACB	2	ACA	2

Distribution of Answers, by Sciences, in the Twenty-Seven Combinations.

All Grades Included.

Physiology	*Physiography*	*Biology*	*Physics*	*Chemistry*	*All Grades and Sciences Combined*
AAA 424	AAA 273	AAA 231	CCC 324	CBC 300	AAA 1157
BAA 258	CAC 227	CAA 164	CAC 199	CCC 281	CCC 1128
CAA 237	CAA 202	CCC 162	CBC 188	CAC 229	CAA 954
CCC 160	CCC 201	BAA 159	AAA 178	CAA 195	CBC 926
BAB 94	CBC 194	CBC 159	CAA 156	CAB 136	CAC 870
CBA 85	BAA 131	CAC 139	AAC 97	CBB 101	BAA 714
CBC 85	BAC 105	CAB 104	BAA 97	BBC 90	CAB 479
CBB 84	AAC 98	AAB 82	CBB 86	BAA 69	CBB 402
CAC 76	CAB 85	CBB 80	CAB 84	BAC 63	BAC 362
CAB 70	AAB 58	CBA 72	BAC 82	CBA 61	AAC 323
AAB 68	BAB 53	AAC 65	BBC 60	CCB 54	CBA 303
CCB 53	CBB 51	BAB 64	BCC 42	AAA 51	BAB 273
BAC 52	CBA 50	BAC 60	CCB 42	BCC 40	AAB 268
BBB 51	CCB 42	BBA 43	BAB 35	AAC 36	BBC 256
BBA 50	BBB 38	BBC 41	CAB 35	ABC 36	CCB 230
ABA 30	BBC 36	BBB 39	AAB 32	CCA 29	BBA 171
BBC 29	BBA 30	CCB 39	BBA 32	AAB 28	BBB 167
AAC 27	BCC 25	ABA 35	ABC 31	BAB 27	BCC 155
ABB 17	ABC 22	BCC 33	CCA 19	ACC 18	ABA 125
CCA 17	CCA 17	ABC 27	ABA 29	ABA 17	ABC 125
BCB 15	ABA 14	ABB 26	BBB 23	BBA 16	CCA 116
BCC 15	ACA 10	CCA 23	ACC 21	BBB 16	ABB 78
BCA 10	ACC 10	BCB 18	BCA 17	ABB 15	ACC 67
ABC 9	BCB 9	ACC 12	ABB 13	ACB 10	BCB 63
ACA 6	ABB 7	ACB 9	BCB 12	BCB 9	BCA 44
ACC 6	BCA 7	ACA 5	ACA 7	BCA 5	ACB 34
ACB 4	ACB 6	BCA 5	ACB 5	ACA 1	ACA 29

CHAPTER XIII.

CORRELATION OF THE RANKS OF THE COMBINATIONS.

EXAMINATION of the ranks of combinations has thrown light upon certain specific tendencies in each grade and science which are characteristic of the reactions of children to topics of science; but there is no guarantee that the comparisons between these grades and sciences are not the results of mere coincidence, however much the evidence may point in the other direction. For example, it might be argued that the laws of chance have brought about the close agreement of the three upper and lower ranks as found in the different grades. It might be even more plausibly argued, pending investigation, that the agreement in the six ranks mentioned might be completely nullified by the disagreement in rank of the other twenty-one combinations.

Again, certain extreme differences are obvious between the lower and upper grades. Are these differences in degree or in kind? Are they so great that the combinations which rank high in the fifth grade rank low in the eighth grade, and vice versa? Or are there fundamental principles of learning which apply almost equally to any grade, high or low, which make certain combinations practically impossible under any conditions, and others equally sure to be characteristic of the reaction of children in any grade? The real nature and extent of the differences between grades is only to be measured by examination of the intermediate, as well as the extreme ranges of the ranks.

It is expected that certain pairs of sciences will show much agreement in the position of their combinations, and that other pairs will show decided disagreement in the same respect. Which are these sciences, and what is the extent of their relation in each case?

In some instances one step in rank is the result of a large difference in the number of answers falling under the two combinations; in other cases one answer alone comprises the step. These positions in rank, therefore, are not of equal significance.

To discover and record all such qualifying instances in the tables of rank into which the combinations are distributed in the different grades and sciences would require an unreasonable and unprofitable minutiæ in the treatment of these data. It is sufficient if the general comparisons are proved to be characteristic of the true status of the reac-

tions of the children. Ranks of this type are best compared by means of the modified Pearson Coefficient of Correlation,[1] which is computed by the formula:

$$r = \frac{S(xy)}{\sqrt{S(x^2)} \cdot \sqrt{S(y^2)}}$$

in which x and y are the respective deviations from the medians of the two distributions compared. This formula takes into account not only the rank, but the size of each of the measures. A high correlation between the ranks of the twenty-seven combinations in two grades of a certain science, or two sciences of a certain grade, would indicate a marked agreement in the order in which the combinations came and in the size of the steps between them; a strong negative correlation would indicate that the combinations which ranked high in one ranked low in the other, with approximately equivalent steps. In either case some underlying principle would be in evidence, and some profitable conclusion might be derived as an interpretation of the correlation. But if a value approaching zero were obtained for the correlation, it would be apparent that a haphazard arrangement resulting from the influence of the laws of chance was present.

There are 465 possible correlations between these ranks for six grades and five sciences. The possible significance of each of these has been carefully studied, and the ones which have most bearing on the problems stated above are the correlations between the ranks of combinations in the different grades in each science and in the different sciences in each grade. This requires the computation of the coefficient of correlation for one hundred and ninety-five pairs of ranks. The data is recorded in Table XIX.

At the first glance, the exceptional strength of the correlations is to be observed. Every correlation is positive, 185 out of 195 being strongly so—over +.500. According to Rugg,[2] a correlation of .60—.70, especially with as many cases as found in these comparisons, is decidedly high. If that interpretation be reasonable, then some of the correlations in this table indeed approach perfection. The rankings of the combinations in these grades and sciences have not been haphazard, nor under the appreciable influence of the laws of probability. The interpretations and comparisons which may be made from these data are, therefore, founded upon fundamental principles rather than mere coincidence in the arrangement of the ranks.

[1] Alexander, Carter: "School Statistics and Publicity," page 185.

[2] Rugg, H. O.: "Statistical Methods Applied to Education," page 256.

Of course, certain grades are more closely correlated than others. It would seem most reasonable, without proof, that if the grades are arranged in the order of their advancement—5, 6r, 6x, 7r, 7x, 8—as has been indicated by other data of this study, the coefficients of correlation would rank themselves in the order of the adjacency of the two grades compared—that is, as the 5th grade is correlated successively with the 6r, 6x, 7r, 7x, and 8th grade, the coefficients would successively decrease; or as the 6x grade was correlated with the others, the coefficient would have the greatest value in connection with the grades only one position removed in series (6r, 7r), a lower value with those grades two positions removed (5, 7x), and the lowest value with the grade three positions removed (8th). Out of 180 correlations tabulated in Table XIX. for the sciences (each correlation except identities—+.1.00—appearing twice so that this condition could be easily seen), only 5 are exceptions to this expectation, and are marked with a sign (*). From the arrangement of the combination of any science in the 5th grade to the arrangement of the same combinations in the 8th grade, there is a series of small successive differences advancing through the intermediate grades in the order—5, 6r, 6x, 7r, 7x, 8—strongly confirming this order of the grades as determined by other data.

The nature of the improvement in the reaction of children toward science, grade by grade, has already been critically analyzed in Chapter XII., using the data of the three highest and the three lowest combinations in rank. These correlations show that whatever conclusions and comparisons were made from the few combinations is solidly confirmed by the distribution of the entire twenty-seven combinations.

Interesting confirmation of another relation is furnished by these correlations. In deciding whether the "last three grammar grades" in the two types of schools should be considered on the basis of the proximity to graduation or by their numerical value, it has been demonstrated, by other data, that the latter method would combine the more similar classes. This is confirmed by the following correlations, all of which are positive:

GRADES.

	6 R with		*7 R with*		*7X with*	
Science	*5*	*6x*	*6x*	*7x*	*7r*	*8*
Physiology	.744	.881	*.962	.960	.960	.931
Physiography	.894	.963	.955	.988	.988	.968
Biology	.726	.897	.776	.889	.889	.875
Physics	.923	.968	.862	.878	.878	.726
Chemistry	.940	.966	.870	.952	.952	.872

In every science the 6th R grade correlates more closely with the 6th X grade than with the 5th grade. With but one exception, marked (*), and that by a quantity of .002, the 7th R grade correlates more closely with the 7th X grade than with the 6th X grade. In every case the 7th X grade correlates more closely with the 7th R grade than with the 8th. This is a confirmation of the grouping previously determined as more appropriate—that is, grades 5, 6r-6x, 7r-7x, 8, rather than grades 5-6r, 6x-7r, 7x-8.

It might be expected that in confirmation of the ranking of the five sciences in the order of their increasing difficulty as previously determined (Physiology, Physiography, Biology, Physics, Chemistry), that the sciences nearest each other in this rank order would show the closest correlation as to their combinations. Such proved to be decidedly the case, for out of 150 correlations between the different sciences recorded in Table XIX., only 15 are exceptions—that is, in the correlations between Biology and the other sciences, the highest correlations are with the sciences only one position removed (Physiography, Physics), and the correlations with the scienees two positions removed (Physiology, Chemistry) are less. When Physiology is correlated with the other sciences, the value of the correlation decreases successively from Physiography, the nearest to Physiology in rank, to Chemistry, the most remote. When the sciences are ranked in this order, therefore, the change in the arrangement and value of the combinations progresses rather uniformly from the least difficult to the most difficult science, confirming the order of the sciences as determined by other data—e. g., Physiology, Physiography, Biology, Physics, Chemistry.

It is interesting to note that although in the fifth grade, Chemistry, the hardest subject, correlates fairly high with Physiology, the easiest subject, but in the higher grades (7th and 8th) the correlations are much lower. Fifth-grade children find any science difficult; but as they progress into higher grades, the assimilability of Physiology increases so much more rapidly than that of Chemistry that an increasing dissimilarity is noticeable in the ranks of the combinations. In all grades, however, the correlations between Chemistry and Physics, two difficult subjects, and Physiology and Physiography, two sciences of easy assimilability, remains high.

TABLE XIX.

Correlation of the Ranks of the Twenty-Seven Combinations, By Pearson's Formula.

In the Sciences.

PHYSIOLOGY.

Grade	*5*	*6r*	*6x*	*7r*	*7x*	*8*
5	1.0000	.7437	.7261	.6160	.5101	.4605
6r	.7437	1.0000	.8812	.8251	.7623	.6612
6x	.7261	.8812	1.0000	.9620	.9268	.8780
7r	.6160	.8251	.9620	1.0000	.9603	.9326
7x	.5101	.7623	.9268	.9603	1.0000	.9313
8	.4605	.6612	.8780	.9326	.9313	1.0000

PHYSIOGRAPHY.

Grade	*5*	*6r*	*6x*	*7r*	*7x*	*8*
5	1.0000	.8943	.8596	.7389	.6077	.5399
6r	.8943	1.0000	.9627	.8072	.7986	.7705
6x	.8596	.9627	1.0000	.9550	.8588	.8422
7r	.7389	.8072	.9550	1.0000	.9881	.9625
7x	.6077	.7986	.8588	.9881	1.0000	.9685
8	.5399	.7705	.8422	.9625	.9685	1.0000

BIOLOGY.

Grade	*5*	*6r*	*6x*	*7r*	*7x*	*8*
5	1.0000	.7256	*.8102	.5588	.4354	.3499
6r	.7256	1.0000	.8969	.8206	.7571	.5696
6x	.8102	.8969	1.0000	.7756	.7111	.5706
7r	.5588	.8206	*.7756	1.0000	.8892	.8728
7x	.4354	.7571	.7111	.8892	1.0000	.8752
8	.3499	.5696	.5706	.8728	.8752	1.0000

PHYSICS.

Grade	*5*	*6r*	*6x*	*7r*	*7x*	*8*
5	1.0000	.9232	.9018	.6598	.6534	.2457
6r	.9232	1.0000	.9683	.8216	.8095	.4435
6x	.9018	.9683	1.0000	.8622	.8303	.5623
7r	.6598	.8216	.8622	1.0000	.8780	.8000
7x	.6534	.8095	.8303	.8780	1.0000	.7257
8	.2457	.4435	.5623	.8000	.7257	1.0000

CHEMISTRY.

Grade	*5*	*6r*	*6x*	*7r*	*7x*	*8*
5	1.0000	.9404	*.5839	.6702	.6330	.4303
6r	.9404	1.0000	.9565	.8792	.8112	.6570
6x	.5839	.9665	1.0000	.8696	*.8933	.6789
7r	.6702	.8792	*.8696	1.0000	.9523	.8352
7x	.6330	.8112	.8933	.9523	1.0000	.8720
8	.4303	.6570	.6789	.8352	.8720	1.0000

In the Grades.

FIFTH GRADE.

Science	*Physiology*	*Physiography*	*Biology*	*Physics*	*Chemistry*
Physiology	1.0000	.7244	.8486	*.7006	.8538
Physiography	.7244	1.0000	.8837	.8892	.8997
Biology	.8486	.8837	1.0000	.9187	.9486
Physics	.7006	.8892	.9187	1.0000	.9663
Chemistry	.8538	.8997	.9486	.9663	1.0000

SIXTH R GRADE.

Science	*Physiology*	*Physiography*	*Biology*	*Physics*	*Chemistry*
Physiology	1.0000	.7980	.6045	.5508	*.6267
Physiography	.7980	1.0000	.8980	.8738	.8531
Biology	.6045	.8980	1.0000	.6305	.7509
Physics	.5508	.8738	*.6305	1.0000	.9408
Chemistry	.6267	.8531	*.7509	.9408	1.0000

SIXTH X GRADE.

Science	*Physiology*	*Physiography*	*Biology*	*Physics*	*Chemistry*
Physiology	1.0000	.7623	.6988	.5195	.3392
Physiography	.7623	1.0000	.8375	*.8498	.7295
Biology	.6988	.8375	1.0000	.8722	.6346
Physics	.5195	.8498	.8722	1.0000	.8760
Chemistry	.3392	.7295	*.6346	.8760	1.0000

SEVENTH R GRADE.

Science	*Physiology*	*Physiography*	*Biology*	*Physics*	*Chemistry*
Physiology	1.0000	.8160	*.8563	.6175	.3223
Physiography	.8160	1.0000	.8976	*.9311	.7193
Biology	.8563	.8976	1.0000	.7927	.6466
Physics	.6175	*.9311	.7927	1.0000	.7570
Chemistry	.3223	.7193	*.6466	.7570	1.0000

SEVENTH X GRADE.

Science	*Physiology*	*Physiography*	*Biology*	*Physics*	*Chemistry*
Physiology	1.0000	.8608	.8149	.5658	.3643
Physiography	.8608	1.0000	.8853	.8056	.6180
Biology	.8149	.8853	1.0000	.6825	.5471
Physics	.5658	*.8056	.6825	1.0000	.7141
Chemistry	.3643	.6180	*.5471	.7141	1.0000

EIGHTH GRADE.

Science	*Physiology*	*Physiography*	*Biology*	*Physics*	*Chemistry*
Physiology	1.0000	.8198	*.9230	.8371	.4423
Physiography	.8198	1.0000	.9281	*.9559	.8017
Biology	.9230	.9281	1.0000	.9292	.6518
Physics	.8371	.9559	*.9292	1.0000	.7454
Chemistry	.44423	*.8017	.6518	.7454	1.0000

CHAPTER XIV.

THE UNDERLYING TYPE FOR THE RANKS OF THE COMBINATIONS.

WITH these exceedingly high correlations between the responses of children to the test questions in different grades and sciences, with the apparently complete elimination of the laws of probability in favor of some underlying fundamental arrangement of the combinations, the question arises: What is this fundamental arrangement? The children have reacted decidedly in a certain direction; what is that direction?

Of the twenty-seven combinations of A, B, and C marks in groups of three, AAA is admittedly the best, CCC the poorest, and BBB the exact intermediate achievement. But, depending on the point of view, either of three combinations may be considered second best—

BAA, ABA, AAB;

and either of six combinations third—

CAA, ACA, AAC, ABB, BBA, BAB,

etc., ranked as to the actual quality of the combination of marks.

Either of the three phases of the child's reaction—i. e., previous knowledge, power of direct assimilation, and power of application—may be considered as of primary importance in determining the quality of the combination. One or the other will necessarily be of secondary importance, and of tertiary importance, respectively. In other words, if we were to rank these twenty-seven combinations in exact order as better or poorer marks, we would have to decide which of the three phases we would consider as of primary importance, having all its A's grouped in the first division of nine ranks, its B's and C's in the second and third divisions of nine ranks; which of the two remaining phases, being of secondary importance, would have its A's grouped in the upper third, its B's in the middle third, and its C's in the lower third of each nine-rank division; and which phase would then be left of tertiary importance to distribute its A's, B's, and C's successively over all the twenty-seven ranks.

If these phases—(1) previous knowledge, (2) direct assimilation, (3) power of application—are arranged in all possible combinations as to relative importance, six differ-

ent groups, representing six different points of view, appear.

Group	*I.*	*II.*	*III.*	*IV.*	*V.*	*VI.*
Primary	1	1	2	2	3	3
Secondary	2	3	1	3	1	2
Tertiary	3	2	3	1	2	1

The combinations would rank under each group as follows:

Rank *Group*	*I.*	*II.*	*III.*	*IV.*	*V.*	*VI.*
1	AAA	AAA	AAA	AAA	AAA	AAA
2	AAB	ABA	AAB	BAA	ABA	BAA
3	AAC	ACA	AAC	CAA	ACA	CAA
4	ABA	AAB	BAA	AAB	BAA	ABA
5	ABB	ABB	BAB	BAB	BBA	BBA
6	ABC	ACB	BAC	CAB	BCA	CBA
7	ACA	AAC	CAA	AAC	CAA	ACA
8	ACB	ABC	CAB	BAC	CBA	BCA
9	ACC	ACC	CAC	CAC	CCA	CCA
10	BAA	BAA	ABA	ABA	AAB	AAB
11	BAB	BBA	ABB	BBA	ABB	BAB
12	BAC	BCA	ABC	CBA	ACB	CAB
13	BBA	BAB	BBA	ABB	BAB	ABB
14	BBB	BBB	BBB	BBB	BBB	BBB
15	BBC	BCB	BBC	CBB	BCB	CBB
16	BCA	BAC	CBA	ABC	CAB	ACB
17	BCB	BBC	CBB	BBC	CBB	BCB
18	BCC	BCC	CBC	CBC	CCB	CCB
19	CAA	CAA	ACA	ACA	AAC	AAC
20	CAB	CBA	ACB	BCA	ABC	BAC
21	CAC	CCA	ACC	CCA	ACC	CAC
22	CBA	CAB	BCA	ACB	BAC	ABC
23	CBB	CBB	BCB	BCB	BBC	BBC
24	CBC	CCB	BCC	CCB	BCC	CBC
25	CCA	CAC	CCA	ACC	CAC	ACC
26	CCB	CBC	CCB	BCC	CBC	BCC
27	CCC	CCC	CCC	CCC	CCC	CCC

The rankings of each group furnish a basis for different, but not necessarily entirely conflicting, interpretations as to the purposes and methods of science instruction to children and the type of results which would be expected from the teaching. For example, the combinations under Group I. are arranged on the assumption that the best students are those whose previous knowledge is the greatest; and they would first be roughly grouped as good, indifferent, and bad on this basis. Each of these three groups would then be subdivided according to the relative powers in direct assimilation, and within these secondary groups ability in application of the principles assimilated would fix the final exact arrangement. In other words, if the best students in a class are to be selected—students to whom a science could be most readily taught—a teacher would first choose those who had a previous knowledge of the science, saying: "Learning proceeds from the known to the unknown." From this group she would select those who could most readily assimilate the direct statements of the science, saying: "Learning must come before use." Finally, she would pick out those who could best apply their knowledge.

Leaving out the attribute of quality and substituting that of number, if the arrangement of Group I. was characteristic of the order in which the reaction of children could be ranked from largest to smallest groups, then it would be inferred that more children possessed an adequate previous knowledge of a typical science than did not; that a somewhat smaller number of children were able to use this knowledge in a successful understanding or assimilation of the new direct statements of the science presented to them; that the least characteristic ability in children, the development of which would cost the teacher the most labor and give the least reward, would be the power of application of the principles of the science.

To another teacher the interpretations of Group VI. might appeal, as she considered the power to apply knowledge the most desirable quality among her pupils. She would select her best upon this basis, saying: "Knowledge you can't use is worse than none." She would then choose those who had the best assimilative power in order to acquire the knowledge to apply, and would consider previous knowledge as the least harmful deficiency, saying: "He that knows not, and knows that he knows not, is ignorant; teach him."

Substituting number for quality, the statement would be made from the arrangement of Group VI. that the most noticeable characteristic of children is their ability to apply the facts of science which they have learned, and to reason further along the lines which have been directly suggested to them. Their next most obvious ability is in the power of directly assimilating information, but that few of them possess any store of previous knowledge upon which to build—this being of minor importance, however, as the deficiency is to be supplied.

These interpretations of the arrangement of Groups I. and VI. are illustrative only. It is obvious that similar processes of reasoning may be applied to each of the other groups. Indeed, from each one a most plausible argument may be derived as to certain ideals to be the basic principles of the method of science teaching to children of the grades. Interpreting an imaginary condition where the greater numbers of the children possessed abilities as indicated in the combinations of the upper ranks, more than one incongruous situation is postulated. It would be interesting to be able to judge many of the educational theories of this present moment in the light of the situation which would exist if their ideals could be suddenly accomplished.

In order to ascertain which of these six groups most nearly represent the actual performance of the 9,819 children of the last three grammar grades who answered the

tests, a correlation between the ranks of the twenty-seven combinations in each grade (Table XVIII.) and in each science (Table XVIII.) and the rank order of the combinations in each of the six groups was computed. Since only ranks, and not quantities, are involved in these six ideal groups, Pearson's formula does not apply, but the Rank Order Correlation according to Spearman must be used.

This is computed from the formula, $r = \frac{6S(d^2)}{n(n^2-1)}$

in which d = the difference in the rank of a combination in the two distributions and n = the number of ranks.[1]

The rank of the combinations under the six groups are the theoretical ideals based upon six different points of view. The ranks of the combinations as determined by the response of the children, nearly ten thousand of them, is the only one that actually exists. Correlation will show which of the six ideals is most nearly approached by the actual distribution of ranks, and, therefore, which point of view is most rational in the training of children of the grades in science. It might be confidently expected that this point of view would vary in the different grades and sciences, according to the age and abilities of the children and the diversity of subject-matter. If, however, the correlations for all six grades and five sciences should agree under one single group of ranked combinations, it would be obvious that the interpretation of this ideal combination would represent the strongest underlying principle in the reaction of children of each of the last three grammar grades to science in general. The data of these correlations are recorded in Table XX.

TABLE XX.

CORRELATION OF THE RANKS OF THE TWENTY-SEVEN COMBINATIONS WITH THE SIX TYPES OF IDEAL ORDERS.

	IDEAL ORDER TYPE.											
	Cor. I.	*R*	*Cor. II.*	*R*	*Cor. III.*	*R*	*Cor. IV.*	*R*	*Cor. V.*	*R*	*Cor. VI.*	*R*
Grade												
5	—.545	5	—.678	6	+.132	2	+.229	1	—.376	4	—.163	3
6r	—.345	5	—.497	6	+.357	2	+.438	1	—.254	4	—.020	3
6k	—.413	6	—.382	5	+.320	2	+.419	1	—.259	4	—.015	3
7r	—.223	5	—.398	6	+.519	2	+.575	1	—.199	4	—.044	3
7x	—.145	4	—.339	6	+.563	2	+.627	1	—.168	5	+.072	3
8	—.066	5	—.157	6	+.523	2	+.729	1	—.054	4	+.161	3
	Cor. I.	*R*	*Cor. II.*	*R*	*Cor. III.*	*R*	*Cor. IV.*	*R*	*Cor. V.*	*R*	*Cor. VI.*	*R*
Science												
Physiology	—.250	5	—.369	6	+.445	2	+.588	1	+.079	4	+.311	3
Physiography	—.206	4	—.393	6	+.500	2	+.563	1	—.214	5	+.082	3
Biology	—.060	4	—.355	6	+.523	2	+.605	1	—.115	5	+.127	3
Physics	—.074	3	—.547	6	+.307	2	+.373	1	—.383	5	—.149	4
Chemistry	—.518	5	—.690	6	+.154	2	+.217	1	—.501	4	—.273	3

[1] See Alexander, Carter: "School Statistics and Publicity," page 184.

One underlying principle influences and determines the rank of the combinations in all grades and sciences. Two groups of the six stand out with overwhelming prominence. Interpretations based on the arrangement of the combinations under the order of Group IV. are sound; the order of Group III. is of but slightly less significance; but conclusions based on the orders of the other groups cannot be reconciled to the actual conditions, since the correlations of the actual ranks of the combinations with these ideal groups is either haphazard or strongly negative. Interpretations, of course, will apply to the majority of children; there are always groups of individuals both above and below the average intelligence who prove to be exceptions to any pedagogical rule.

In Group IV. direct assimilation is of primary importance, power of application secondary, and previous knowledge of tertiary rank. The first power to develop in a child is that of direct assimilation, and this ability keeps ahead in all development. A text in science written for the grades must abound in direct statements of fact, plain illustrative material, and leave little to be inferred. Successful teaching of science in the grades must be judged largely by the extent to which children master the direct assignments of the day. An equivalent success in reasoning from the simple facts learned must not be expected. A book which is full of the so-called "thought questions" is not altogether the best for grade instruction, however applicable that method may be to high-school classes. The powers of logical reasoning have not yet developed in the minds of grade children, and abstract principles cannot be visualized by them.

Neither can reliance be placed on any appreciable previous knowledge possessed by the children. For the grades, science must be even more simple in idea than in language. An eighth-grade child is abundantly able to read a fairly technical discussion concerning the hardness of water, or the magnetic field through a coil of wire; but it is not at all certain that he has ever inquired into the reason for the use of ammonia or soda in the home, or that he has ever taken the cover off an electric bell.

In fact, the self-acquired knowledge of children goes but little beyond the observation of obvious cause and effect. The much-proclaimed curiosity of children rarely searches out principles. It would seem that the most familiar objects would be the best understood, but the tendency to take familiar things for granted largely neutralizes the spirit of inquiry. This tendency often persists even to adult life.

The writer found, in a study of the previous knowledge of several hundred of his Normal and college students, in beginning Chemistry, that over half of them did not know whether air was one substance or a mixture of substances.[1] The question arises: How familiar must a thing be in order that the facts about it may be common knowledge?

The strong positive correlations of Group III., in all cases only slightly less than the corresponding correlations for Group IV., show that in respect to previous knowledge and power of application there are two approximately equal types of reactions. The more appropriate interpretation (Group IV.) appraises the ability to reason from or to apply the knowledge gained by direct assimilation as of greater value than the wide experience which would have supplied a store of previous knowledge. This experience, being a product of environment, is not under the control of the child, and he cannot be held responsible for its lack, except to the degree in which close observation would have supplied it. Of course, memory functions in the retention of these experiences.

The other interpretation (Group III.) would assign the more importance to this experience rather than to the ability to apply knowledge. It is obvious that there are two large and not very dissimilar groups of children—one with better memory than logic, the other with better reasoning power than memory. Of course, one ability by no means eliminates the other, either in the individual or in the mass; but one or the other merely predominates to a greater or less degree.

General Science instruction in the grades, therefore, must be studied and planned from two angles—content and method. The content should be the most appropriate to the child's environment; but, above all, it should be assimilable. Real principles of science, it appears, are not assimilated by children of the fifth grade and below; Physiology and Physiography are appropriate in the sixth grade; Biology, and possibly Physics, may be successfully taught in the seventh grade; Physics can be assimilated in the eighth grade; while the laws and phenomena of Chemistry seem unsuited to any grade. This order of assimilability is radically different from the rank of the sciences in importance in the eighteen texts, most of them for high-school use, in which Physics is given the most adequate treatment, and Physiography, Biology, Physiology, and Chemistry follow in the order named.

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[1] Webb, H. A.: "A Preliminary Test in Chemistry," Journal of Educational Psychology, Vol. X., No. 1, page 36 (January, 1919).

The method of science instruction in the grades should make full use of the predominant power of the child to directly assimilate facts—an ability well illustrated by the well-known ease with which they master the language. Efforts to cause powers of reason and observation to function when by the laws of child psychology these powers are in a rudimentary stage of development will result in waste of energy on the part of both teacher and child.

As the use of General Science spreads to the grades, it is hoped that both content and method will be built upon a firm foundation of educational principles determined by experiment. As in the great manufacturing industries of our country, the experimenting should be done in the laboratory, not in the factory. Tests on small, but adequate, groups of children should be relied upon more and more to determine the wisdom of our methods, with all the accuracy of the analytical chemist brought to bear on the problem. With the nation awake to the great waste of effort which some of our educational practices permit, and with an appreciation of the delicacy of the precious material which our teachers attempt to mold and fashion into the finished product as good citizens, each able to make a living and appreciate the necessary refinements of culture, a truly scientific spirit is demanded in education. The standard test, the survey, and other types of quantitative educational analysis, have of necessity been evolved. There never was a time when dogmatic statements based on mere opinion were less appropriate. It is hoped that this study has contributed in some degree to the sum of experimental knowledge in education.

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